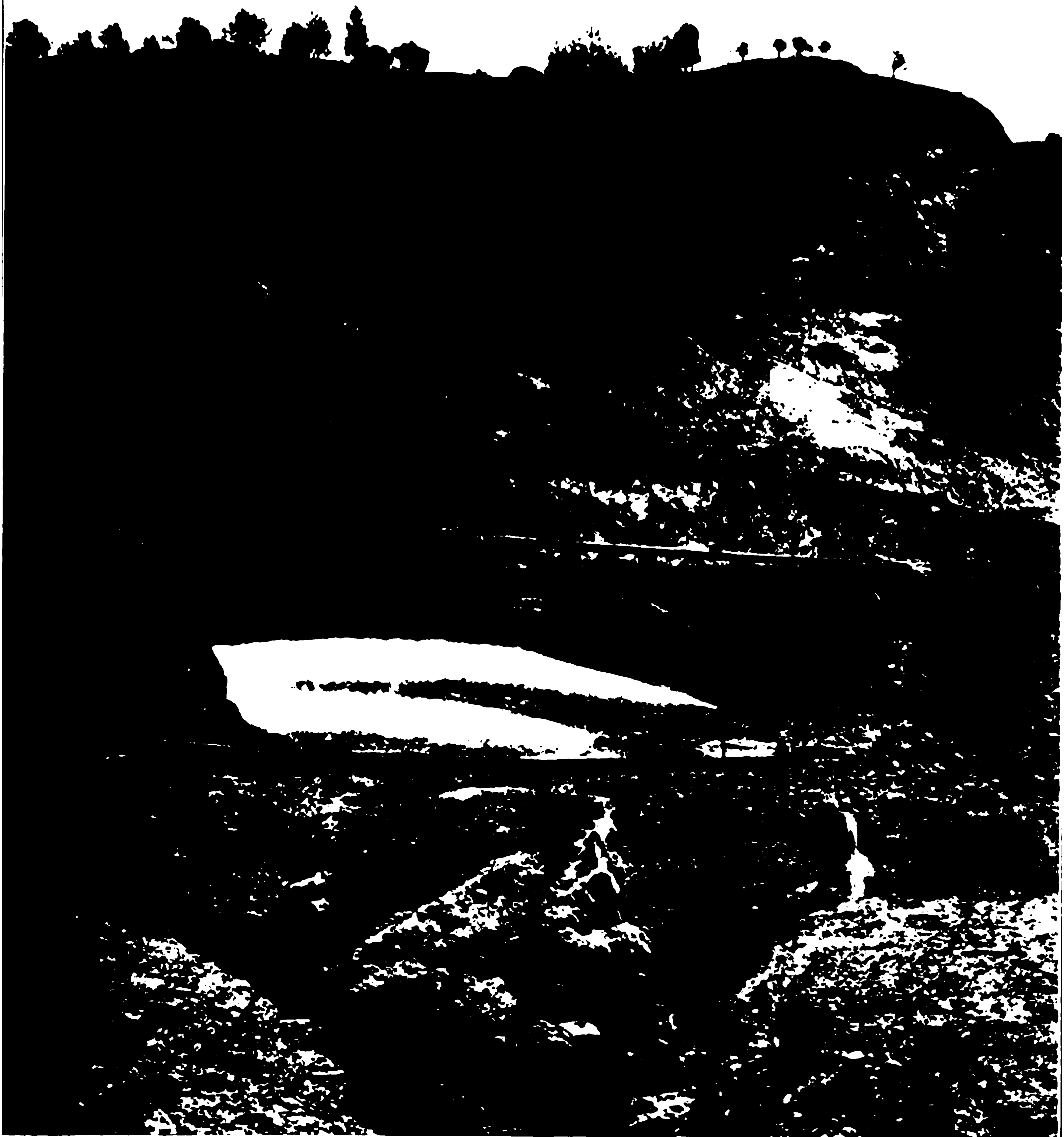

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DENUDATION AND EROSION

IN THE

SOUTHERN APPALACHIAN REGION

AND THE

MONONGAHELA BASIN

BY

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DENUDATION AND EROSION IN THE SOUTHERN APPALACHIAN REGION AND IN THE MONONGAHELA RIVER BASIN.

By L. C. Glenn.

INTRODUCTION.

This report presents a brief summary of the results of an examination of the southern Appalachian region during the field seasons of 1904 and 1905 and of the Monongahela Basin in West Virginia and Pennsylvania in 1907, made for the purpose of studying the effect of deforestation and consequent erosion of the steep mountain slopes on geologic, hydrologic, and economic conditions, both in the mountain region itself and in the surrounding areas through which the many streams that rise in the high Appalachians flow on their way to the Mississippi, the Gulf, or the Atlantic.

In the southern Appalachians a detailed examination was made of an area some 400 miles long, reaching from a point near Pulaski, Va., southward to Gadsden, Ala., and from 75 to 125 miles wide, extending from the valley of east Tennessee, in which Tennessee and Holston Rivers flow, eastward across the mountains and out some distance on the Piedmont Plateau. This area, which comprises about 35,000 square miles, includes a part of southwestern Virginia, the eastern borders of Tennessee, the western part of North Carolina, the northwestern part of South Carolina, the northern part of Georgia, and a portion of northeastern Alabama. In West Virginia and Pennsylvania a detailed examination was made of the entire basin of the Monongahela.

A more cursory examination was made of an additional area comprising about 15,000 square miles of the southern Appalachian region, the work being carried throughout the length of several of the main rivers that head in the region and flow out across the bordering plains. No attempt was made to study the valleys of all of the many tributaries of these streams. Even had such detailed work been possible in the time available, it would not have been desirable, since in any portion of a major stream basin in which the rocks are homogeneous the features of one minor tributary are much like those of any other. Consequently, selected minor stream basins were examined and careful inquiry was made as to others. A comparison of the results of inquiry with the results of subsequent actual observation has served to check the reports and to give, it is believed, an adequate idea of the conditions in the entire area.

It was at first intended to examine only the upper or mountainous portion of the stream basins, but in the course of this work it was found that enormous volumes of cobbles, gravels, sands, and clays were being shed from the steep slopes into the mountain streamlets and were working their way down into the major streams, and that the progress of this material was attended by a train of consequences that are disastrous to the owners of the property along the streams. To determine what ultimately became of all of this material, a study was made of the channels of certain major streams after they had left the mountains and were crossing the plains well on their way to the sea.

Tennessee River was followed to its mouth, over 700 miles, from the mountains at its headwaters. The Coosa-Alabama River was studied as far down as Selma, Ala; Chattahoochee River was followed to a point beyond Atlanta, Ga.; Savannah River down to Calhoun Falls, S. C.; the Broad and Saluda down to Columbia, S. C.; the Catawba 100 miles or more

out on the Piedmont Plateau until it had passed the great power plants found along its middle course; the Yadkin from its headwaters along the eastern front of the Blue Ridge far out across the North Carolina Piedmont. New River was examined in detail as far north as Pulaski, Va., and a less detailed examination was made of its lower portion along the Chesapeake and Ohio Railway and its continuation as the Kanawha to below Charleston, W. Va. A

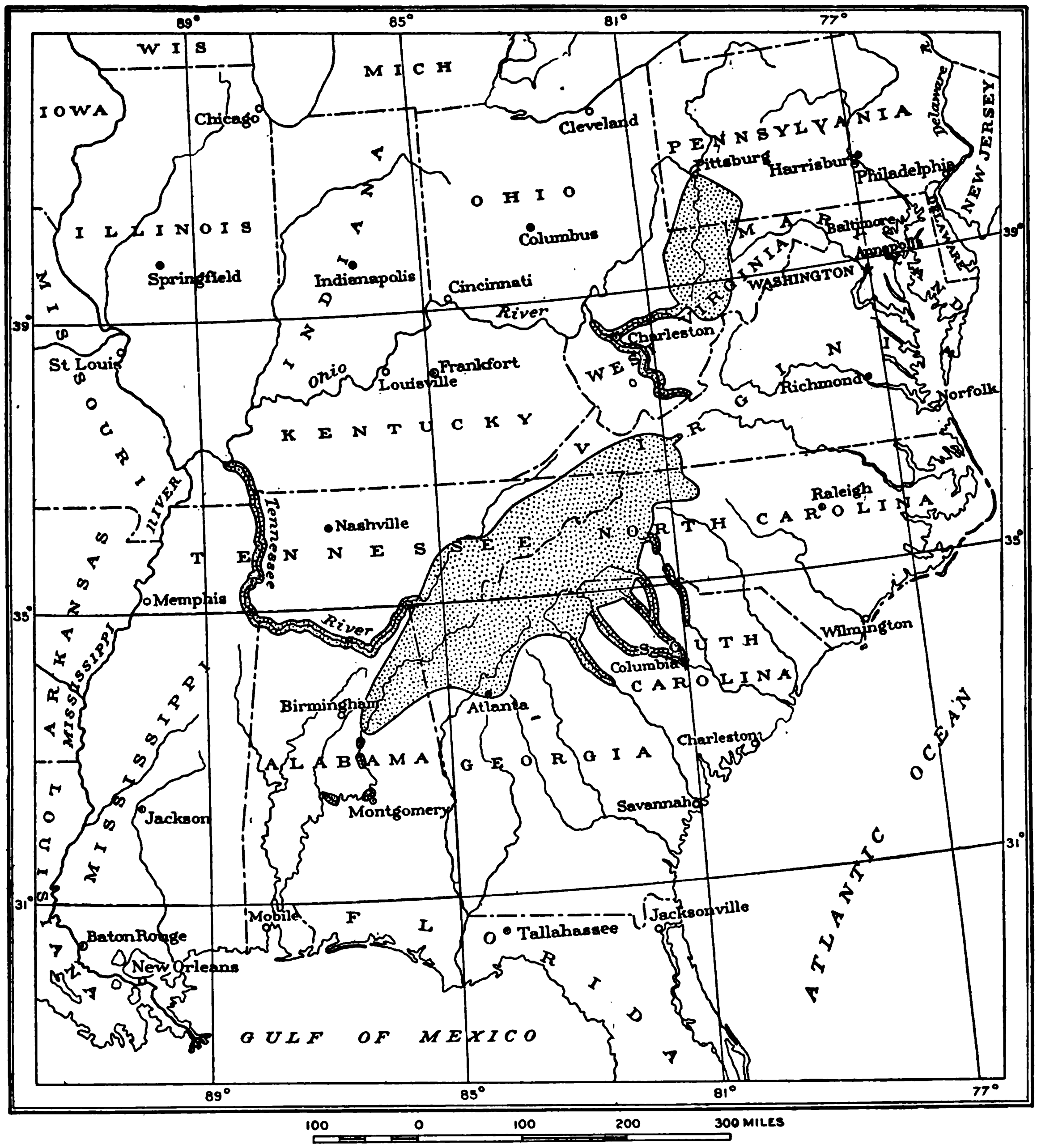

FIGURE 1.—Map showing areas examined.

cursory examination was made of the basin of Elk River, one of the Kanawha's tributaries, from its mouth at Charleston, W. Va., up to its headwaters in northern West Virginia. A detailed examination of the entire basin of the Monongahela River was made, ending with a study of the causes of the disastrous flood of March, 1907, in Pittsburg, Pa. Because of the large proportion of their cleared area kept permanently sodded in grass lands, the basins of New and Mononga-

hela rivers furnish instructive contrasts, as regards erosion, to the streams farther south, where sodded lands are the exception rather than the rule and where erosion is much more active and destructive.

In examining these rivers attention was centered mainly on their channels and flood plains, but considerable information concerning the country adjacent to their courses was also obtained. The areas included in the examination are shown in figure 1.

Where there were roads and trails travel was mainly on horseback; where these were lacking, as along wild stream gorges or rough mountain sides, travel was afoot. The larger streams in the areas below the mountains proper were traversed by means of rowboat, gasoline launch, or river steamer. The region adjacent to nearly every railway in the region was also examined.

It is believed that no important body of facts bearing on the subject of the inquiry escaped notice and that the frequency of recurrence of the conditions noted affords a fair measure of their relative importance as factors in the changes now in progress in the region.

Personal observation was supplemented by inquiries made of county officials who were familiar with local conditions or whose duty it was to maintain roads and bridges or assess the valuation of lands damaged by erosion or by floods.

Much information was also obtained from lumbermen, land owners, and manufacturers, from officers of power, mining, and railway companies, from river men, including captains and pilots of river steamers, and from the United States Army engineers engaged in river improvements in the region. To all of these the writer's indebtedness is gratefully acknowledged.

PHYSICAL FEATURES OF THE SOUTHERN APPALACHIANS.

TOPOGRAPHY.

From the Virginia-North Carolina line the Appalachians extend southwestward 250 miles to northern Georgia, where their ridges almost die out, but farther southwest they rise again and extend some distance into Alabama before they finally disappear. The Appalachian belt proper varies in width from 50 to 70 miles.

The mountains rise from a base that ranges in elevation on the southeast side from 1,000 to 1,200 feet above the sea, and on the northwest side from 900 feet in northwest Georgia to 1,600 feet on the Tennessee-Virginia line. The mountain belt proper is really an elevated plateau walled in on its western margin by a higher mountain range from which numerous short spurs project out upon its general surface. Here and there on the plateau are other short, isolated ranges, one of which, the Black Mountain Range, includes Mount Mitchell, which rises to an elevation of 6,711 feet and is the highest point east of the Rocky Mountains. More than forty peaks rise above 6,000 feet. Almost a hundred square miles are above 5,000 feet, and almost half of the North Carolina portion is above 3,000 feet in elevation. Part of the eastern edge of the plateau is marked by peaks that rise above its general surface level and part by an abrupt escarpment that overlooks the Piedmont Plateau to the east. This eastern edge of the mountain plateau region is called the "Blue Ridge." The general surface of the mountain plateau has been carved by streams into a multitude of hills and minor ridges, and in this region most of the highest areas lie between the headwaters of adjacent major streams, where erosion is and has always been least efficient in lowering the general surface level.

The mountains generally have well rounded soil-clad slopes that show softened outlines. Only here and there do they present abrupt slopes and sheer precipices of bare rock. The profiles are the flowing curves that are characteristic of mature or old mountains rather than the abrupt lines of young mountains.

The higher summits afford magnificent views of wooded mountain slopes with softly rounded outlines or of fertile coves and valleys dotted with fields and homes. Along some river gorges, such as the Linville, the Nolichucky, the Doe, the Big Pigeon, the Nantahala, the Ocoee,

the Tallulah, and the Broad, the mountain walls in many places rise in sheer precipices and the scenery is wild and rugged; along others, such as the New, Watauga, French Broad, Little Tennessee, Hiwassee, Etowah, Saluda, Catawba, and Yadkin, it is usually less wild and rugged but equally picturesque and beautiful.

Except along the river gorges there is usually little in the landscape that is rough and rugged, because deep disintegration has almost everywhere mantled the rock with a soil covering that gives to the surface smooth instead of jagged outlines.

GEOLOGY.

The rocks of the region are principally gneisses, schists, and granites, but include smaller areas of quartzites and limestones, especially in the western part, and volcanic rocks in the northern part. All are ancient, and in many places they have been much folded, crushed, and distorted or have been broken and faulted. In the course of the movements that produced the distortions many new minerals have been formed in the rocks by chemical rearrangement or have been brought into them in solution by circulating water or gases and deposited in cracks and fissures.

Not only are the rocks all ancient, but they have been so long exposed to weathering that they have been deeply rotted, and in most of the region the residual material covers the solid rock, forming in places a layer many feet deep. This disintegrated rock, when protected from erosion, absorbs much of the rainfall and afterward feeds the water slowly to the streams, thus regulating the stream flow by preventing floods when heavy rains fall and excessively low water when dry seasons come.

DRAINAGE.

The region is drained by a multitude of streams whose waters flow to the Ohio, the Tennessee, the Gulf of Mexico, or the Atlantic. The Blue Ridge, lying along the eastern border of the mountain belt, forms the main divide and contains the sources of the principal stream systems of the region. New River occupies the northern part of the area under consideration and flows northwestward, joining the Ohio as the Kanawha. South of it are the Holston, Watauga, Nolichucky, French Broad, Big Pigeon, Tuckasegee, Little Tennessee, Hiwassee, and Ocoee, all flowing westward and forming a part of the Tennessee system. From the southern end of the Appalachians the Coosa and the Chattahoochee flow southwestward into the Gulf of Mexico. The Savannah, Saluda, Broad, Catawba, and Yadkin rivers rise on the steep eastern face of the Blue Ridge escarpment and flow southeastward into the Atlantic.

The drainage from the southern Appalachians is thus radial and far-reaching, and the flow of the streams directly affects the industries and welfare of the people in much the larger part of the southeastern United States.

Most of the small headwater streamlets rise high on the steep mountain sides, flow in narrow gorges, and descend in a few miles by a series of falls and rapids to an elevation between 2,000 and 3,000 feet, uniting to form larger streams, which, as a rule, flow without much additional fall across the middle part of the mountain plateau in broad, open valleys with gently to steeply rounded slopes, but which invariably cut deep, narrow gorges through the chain that forms the western rim of the mountain plateau. Most of the small tributary streams in the middle part of the plateau have considerable fall.

Water powers of 10 to 50 horsepower exist in almost every part of the region, and a series of small mills may be found along a single small stream. Few of the larger streams have sufficient fall to afford much power until they enter the gorges by which they leave the mountains, where their fall is mainly concentrated and where power may be developed in large units.

FORESTS.

The entire region, with the exception of a few high "balds" and an occasional steeply rounded scarp or precipice of bare rock, was originally covered with forests which were remarkable for the extraordinary size and height and the wonderful variety of the trees. About 74

per cent of the area is still forested, but large areas have already been stripped of much or all of their valuable timber by reckless lumbering, forest fires, and agricultural butchery.

Around the southern end of the Appalachians short-leaf yellow pine forms a considerable part of the forest, but elsewhere the cover consists of walnut, cherry, poplar (or tulip), oak, chestnut, hickory, and many other species on the lower and middle slopes; beech, hemlock, and white pine on the higher slopes, and spruce and balsam at greater heights. The trees are larger and more perfect on northern slopes and in coves, where the soil is moister, deeper, and richer. On southern slopes the soil is likely to be dryer and to contain less humus and consequently to be less fertile. The forest there is more open, and both the trees and undergrowth are more stunted. These southern slopes, especially along the Blue Ridge, are in many places steeper also, and these characteristics all combine to make them more liable to erosion. On lands once cut over reproduction of the forest is generally rapid, provided the soil layer has not been removed by erosion before the new growth has had time to establish itself. In a similar way abandoned old fields that have not been denuded of their soil rapidly grow up again.

These southern Appalachian forests form to-day the largest and most valuable hardwood area left in the United States and if properly cared for they may be made the permanent source of our national hardwood supply.

CLIMATE.

The average rainfall in the northern and northwestern parts of the region is in places only 40 to 50 inches a year, but on the southeastern slopes of the Blue Ridge the annual rainfall is greater than in any other part of the United States except the North Pacific coast. The average rainfall in this part of the southern Appalachians is 70 to 80 inches, and the yearly maximum exceeds 105 inches. The rainfall is not uniformly distributed throughout the year, but reaches a maximum either in July and August or, less commonly, in February and March. In summer much of it is torrential in character and the downpours may continue several days. Not unusually it rains 20 or 25 days in a month, and a month's precipitation may reach or exceed 30 inches, and the rainfall in a single day may be as much as 9 inches. In winter a considerable amount of the precipitation is in the form of snow, and by its slow melting this snow, which remains on sheltered northern slopes for some time after it has disappeared in the valleys below, aids greatly in regulating the stream flow.

The climate of the region is much cooler than that of the Atlantic slope to the east or the Mississippi Valley to the west; it is not, however, the same throughout the entire mountain region. Areas close together may differ in elevation more than 5,000 feet and their average temperatures may show differences as marked. On the higher peaks the vegetation is of Canadian type. The northern part, in North Carolina and Virginia, is considerably colder, even at the same elevation, than the southern end, in Alabama. The southern and southeastern slopes are sheltered by the higher crests and chains from the cold waves from the interior of the continent and have a milder and more equable climate than have the northwestern slopes, which are more exposed to cold waves and hence show greater temperature variations than the southeastern slopes. In summer the temperature may fall as low as 40° on the mountain tops, or may rise to 75°, 80°, or 85° in the valleys. From December to March the temperature anywhere in the mountain region may drop below zero for a day or two at a time, and minimum temperatures of −10°, −15°, and −19° F. are recorded for the region. The mean monthly winter temperature for stations at elevations between 3,500 and 4,000 feet ranges from slightly below the freezing point to several degrees above.

In summer it is warm everywhere in the direct rays of the sun, but is cool in the shade, and the nights are cool enough to make blankets necessary. It is said that on some of the higher plateaus in the northern part of the region frost has been known to occur every month in the year. In winter the climate is cold and dry enough to be bracing, but is not harsh and trying, even for delicate constitutions.

The average humidity is not so great as in the surrounding region, but the average rate of wind movement is greater. Direct evaporation is consequently more active than on the plains.

The following table gives the monthly precipitation and mean temperature for a number of selected stations in the region.

Average temperature and precipitation at selected stations.

		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual average.
Linville, N. C. (12 years)	t.	31	30	40	46	58	63	66	65	59	49	40	32	48°
	p.	3.4	5.3	6.1	4.6	3.7	5.3	6.1	5.2	5.6	5.3	3.9	5.7	60.2″
Lenoir, N. C. (31 years)	t.	37	40	46	56	65	72	75	74	66	56	46	38	56°
	p.	4.1	4.5	4.6	3.8	4.7	4.6	4.9	5.9	4.5	3.4	3.2	3.8	52″
Waynesville, N. C. (10 years)	t.	37	36	48	52	62	68	70	70	64	54	46	38	54°
	p.	4.3	5.1	6.4	4.1	3.7	4.4	4.6	4.5	2.4	2.1	2.5	3.6	47.7″
Asheville, N. C. (24 years)	t.	38	40	46	54	63	69	72	71	65	54	45	39	55°
	p.	3.0	3.7	4.2	3.4	3.5	4.1	4.9	4.6	2.9	2.6	2.7	3.0	42.6″
Highlands, N. C. (21 years)	t.	34	35	42	50	58	65	67	66	60	51	42	35	50°
	p.	6.2	8.5	7.8	6.5	4.4	6.9	6.8	7.6	5.8	5.2	5.6	6.9	78.2″
Clayton, Ga. (10 years)	t.	40	39	50	56	66	72	75	74	68	57	48	40	57°
	p.	5.9	7.4	7.8	6.3	3.2	5.3	7.0	7.2	4.9	4.0	3.9	5.6	68.5″
Dahlonega, Ga. (10 years)	t.	41	41	50	58	67	73	75	75	70	60	50	42	58°
	p.	5.3	7.0	6.4	4.3	4.2	5.5	5.9	5.5	4.5	3.0	3.0	5.3	59.9″
Elizabethton, Tenn. (p. 14; t. 15 years)	t.	37	37	46	55	65	73	76	75	68	57	46	38	56°
	p.	2.9	3.5	4.6	3.4	4.4	7.2	4.6	4.1	2.7	2.2	2.4	3.2	45.2″
Knoxville, Tenn. (33 years)	t.	38	41	48	58	66	73	76	75	69	58	47	39	57°
	p.	5.1	4.9	5.6	4.7	3.8	4.2	4.1	4.1	2.9	2.6	3.6	4.1	49.7″
Newport, Tenn. (t. 8; p. 13 years)	t.	38	40	48	57	66	74	77	76	69	58	46	38	57°
	p.	3.6	4.3	5.4	3.6	4.1	4.2	4.3	4.4	2.2	1.8	2.6	3.1	43.6″

t.=temperature, °F.; p.=precipitation in inches.

POPULATION.

The population of the region as a whole averages between 30 and 40 to the square mile. Taken by counties, it ranges from 15 to 75 to the square mile. Most of the towns are small, and the population is in the main rural. In the towns a small proportion of it is colored; in the country it is almost exclusively white and of native parentage, composed of the descendants of the pioneers of the colonial days. Very few foreigners live in the region.

The settlers are most numerous in the valleys, on the low rolling hills of the Asheville Plateau, and in the little coves that nestle among the high mountains, but many isolated cabins, surrounded by small clearings, are found far up on the steep slopes of such of the higher peaks and ridges as have a fertile soil. The more rocky and barren slopes are entirely uninhabited, and one may travel for miles across some of the wilder mountain areas without seeing a cabin or a clearing.

TRANSPORTATION.

RAILWAYS.

Considered as a whole the railway transportation facilities of these mountains are poor. Many of the settlements are 20 to 35 miles from the nearest railway, and this distance in some areas must be traversed by rocky paths or poor mountain roads. One railway crosses the mountains from east to west about midway their length; another crosses their southern end, and these two lines are connected by a line, some 150 miles long, that runs lengthwise along the mountains. Several small lines have been extended into the mountains, and two others are now under construction across them from northwest to southeast. For large lumbering operations narrow-gauge railroads or tramways have been built, and some of these become permanent. Many parts of the region, however, will be remote from transportation lines for years to come.

ROADS.

Very few of the wagon roads have been graded or otherwise improved, so that hauling by wagon is generally slow, difficult, and expensive, yet the price of lumber has become so high

that in many places it is hauled 15 to 25 miles, and within this distance of the railways most of the good lumber has been cut. As the price rises the practicable hauling distance steadily increases.

RIVERS.

The streams are utilized to some extent for floating logs; otherwise there is no river transportation within the region itself, though many of the streams that flow out from the mountains unite on the plains to form navigable rivers. New River joins the Ohio. The Holston, French, Broad, Little Tennessee, and Hiwassee, which are navigable in their lower courses through the valley of east Tennessee, form Tennessee River, which is navigable 650 miles, from Knoxville to its mouth, and touches in its course Tennessee, Georgia, Alabama, Mississippi, and Kentucky. The Oostanaula, Coosawattee, and Etowah, which flow from the southern end of the mountains, become navigable soon after leaving the mountains and unite to form the Coosa, the main head member of the Alabama River system, which is now navigable from Rome, Ga., to below Gadsden, Ala., and when the system of locks and dams now under construction is complete will become navigable down to the Gulf at Mobile. The lower courses of all of the main rivers on the eastern side of the mountains become navigable at the outer edge of the Piedmont Plateau.

RELATION OF INDUSTRIES TO EROSION AND DENUDATION.

AGRICULTURE.

The population is largely agricultural. In the higher mountains grasses grow well and grazing is an important industry. Much of the cleared land there is kept in grass and so is prevented from washing badly, but some of the cleared slopes are so steep that even though kept in grass they soon erode to the bare rock and become useless wastes. During prolonged wet weather the turf and soil become thoroughly softened, and on steep slopes the hoofs of the cattle easily break the turf and start small landslides that quickly develop into gullies. Some of the so-called balds, once well sodded, have become bare, rocky wastes from erosion induced by the trampling of cattle. This conversion of sodded balds into rocky wastes is actively in progress to-day on the top of Roan Mountain.

When first cleared, the land is usually planted in corn for about two or three years, is then for two or three years put in small grain or grass to be mowed—not grazed—and then back into corn for several years. Unless it is well cared for the land has by this time become poor, for it has lost its original humus. The soil has become less porous and less able to absorb the rainfall and erosion begins. Means are rarely taken to prevent or check this erosion, so it increases rapidly and the field is soon abandoned and a new one cleared.

When the clearing is intended for grazing, the preliminary rotation practiced by the more progressive farmers is nearly the same. Corn is planted 2 years, then meadow for 2 years, then corn a year, then grass for permanent pasture. This first pasture sod usually lasts 8 or 10 years, when the land is again put in corn for a year, then oats and grasses are sown, and the sod is again as good as the first one. When properly cared for and not too steep, grazing land should be capable of indefinite use. The erosion of such lands is due chiefly to ignorance and neglect, and the remedy is not reforestation but education. Grazing lands, however, comprise but a small part of the entire area of cleared land, which has recently been estimated by several investigators at 24 per cent of the total mountain area. The writer believes that this estimate is approximately correct, but that it errs, if at all, in slightly overstating the cleared area.

In clearing land only the undergrowth and small trees are as a rule removed. The large trees are killed by girdling and left standing. Many fields are worn out and abandoned before the trees girdled in its clearing have all fallen. Then new grounds are usually cleared beside the abandoned field and the same destructive process is repeated.

The clearing of virgin forests for agriculture is going on steadily from year to year to replace worn-out, eroded, and abandoned lands. When the region was settled, the more level

lands along and near the streams were first cleared and those that have been properly cared for and are out of the reach of the stream floods have remained in cultivation and are in good condition to-day. After these lands had been largely cleared the steeper slopes were next invaded by the axman and then still steeper slopes, so that very much of the land now being cleared is too steep for cultivation under present farm practice and should be kept in forests.

Numerous attempts have been made to estimate the percentage of the area of these mountains that might safely and profitably be cleared for cultivation. These estimates average about 15 per cent. It is difficult to give any definite estimate of such area, for the allowable limit of slope of lands that may be safely cleared—which is generally put at 10° and which alone has usually been considered—is not the only factor of the problem, for the nature of the soil, which is dependent on the geology of the underlying rock formations, and the intelligence and care of the cultivator should also be considered. On some soils 10° may be the maximum slope for safe cultivation; on other soils slopes of 20° do not wash. Slopes themselves may be changed by terracing, and education may so greatly increase the intelligence and care of the cultivator that estimates of cultivable area that consider these varying factors must of necessity vary, and the variation tends to increase the estimate of cultivable area as time passes. The increase, however, must be slow, and for present methods of cultivation 18 to 20 per cent is probably a liberal estimate for the area that may be cleared safely. The present cleared area, 24 per cent, is undoubtedly in excess of the limit of safety under the existing conditions of agriculture.

Tobacco growing has in the past been peculiarly injurious to the soil. The plant requires clean cultivation, and when planted year after year soon exhausts the fertility of the soil, depletes the humus, and leads to erosion and early abandonment. Some 15 or 20 years ago tobacco growing became quite profitable in some sections and lands were rapidly cleared, worked in tobacco a few years, worn out, and abandoned. The effect of this clearing and cultivation on the streams in general will be discussed later.

LUMBERING.

Lumbering has been so active in this region that practically all the timber that is easily accessible to the railway or to streams large enough to float it has been cut. As prices of lumber have advanced the mills have been moved farther back from the railroads until now a part of the product of the small mills is hauled 15 to 25 miles over rough mountain roads, and the owners of the larger mills have built their own logging railways or tram roads back into the heart of even the more distant mountains.

Most of the valuable timber has already passed into the hands of lumbermen, who are now actively buying lands in even the most remote and almost inaccessible localities. Prices of timber lands are rapidly advancing, and if cutting is continued at the present rate the primeval forests of these southern mountains will soon be a thing of the past.

A few large forest tracts are being preserved by private individuals or corporations or are being lumbered according to modern conservative methods, but except in these few areas lumbering is carried on so as to yield the largest possible immediate returns without thought or care for the future.

In recent years a number of large tanneries and several tanning-extract plants have been established in the region, and these insure the destruction of most of the chestnut, chestnut oak, and oak left by the lumbermen. Recently, also, one of the largest wood-pulp plants in the country has been built in the region and has begun to strip the forests and to pollute the stream on which it is located.

Forest fires may follow in the wake of the lumberman and complete the destruction of the young growth, and the blackened waste may be abandoned to the county as not worth paying taxes on. In many places destructive forest fires have not occurred and there the young growth retains possession of the land and begins the production of a second crop of timber, though only a few of the lumbermen in the region are looking ahead far enough to count this second crop as an asset of any value. Very many of them would part with the land for a small price when they have once thoroughly lumbered it.

MINING.

The southern Appalachians are noted for the great variety of their mineral deposits. Although many of these have never been developed, others, such as the deposits of gold, copper, marble, mica, corundum, talc, asbestos, slate, baryta, and kaolin, have become the basis of important mining operations, and annually yield mineral products to the value of several million dollars.

Mining is affecting erosion in several ways, one of which is locally important. The timbering required in underground mining creates a demand for mine props and other timbers. So far this has not been a serious menace to the forests, partly because underground mining operations are not generally extensive throughout the region and partly because the rocks are ancient crystallines that below the limit of surficial weathering are strong enough to stand without much timbering.

Much of the mining, especially of gold and monazite, is of the placer type. The gold mining is centered chiefly around Dahlonega, Ga. Stream gravels are washed to some extent, but mining is most active in the saprolite or surface rock that, though decomposed, is still in place. Entire hillsides are washed down into the streams by hydraulic giants. Careful examination and inquiry, however, failed to show that much damage is being done along the streams within the Dahlonega region itself as a result of this placer mining, partly because there are in most places little or no bottom lands susceptible of cultivation, but chiefly because most of the streams have much fall and sweep away the sand and clay as fast as the mines furnish it, or the frequent floods carry away any material that tends to lodge along the streams. Much of it lodges farther out along the Piedmont part of the streams, where their grade is less and their transporting power is correspondingly reduced, and there it may aid in doing damage.

In the Dahlonega region very little of the upland is cleared and the normal amount of waste furnished to the streams from agricultural lands is small. The streams are consequently able to transport the additional waste furnished by the hydraulic mines; but should the clearing of uplands be extended, as is to be expected, the increased agricultural waste, together with the mine waste, will soon overload the streams and cause the accumulation along their courses of sand and clay which they would then be unable to carry.

Dredging for gold is carried on in some of the streams of the Dahlonega region and large quantities of stream waste are moved in this way. The effect on the stream channels and on the adjacent bottom lands depends on the extent of the pay gravel and on the mode of disposing of the tailings. Where pay gravel underlies the bottoms they are worked and their future agricultural value is largely or entirely destroyed.

After the streams have left the Dahlonega region their slopes and velocity decrease and the waste carried out from the mining region is being deposited along the way, filling the stream channels, lodging on bars, and causing islands to form, thus further obstructing the channels and making overflows easier and the destruction of the bottom farming land more speedy, certain, and complete. With the further clearing of lands that may normally be expected this condition will become constantly worse.

The third and most injurious kind of mining studied in the region is that at Ducktown, Tenn., where sulphur fumes from the roasting and smelting of the copper ores have killed all vegetation for a number of miles around and the perfectly bare surface has eroded with wonderful rapidity (see pp. 24–25, 78–79).

POWER DEVELOPMENT.

Careful estimates made by competent engineers show that the streams of the southern Appalachians afford, in units of considerable size, about 3,000,000 undeveloped horsepower, and probably as many more in small units suitable for a great variety of minor industrial uses. Nearly all of the water power in the mountains has heretofore remained undeveloped because of its inaccessibility, but since the electrical transmission of water power has been made practi-

cable, its utilization has become possible. As the opening of new railroads through the mountains renders the water powers more accessible, as population steadily increases and turns for a livelihood to new avenues of industrial activity, and as cotton mills and other manufacturing enterprises in the South utilize the available power sites in the Piedmont, the demand for this mountain stream power must yearly increase and will naturally lead to its utilization. At any reasonable valuation per horsepower the undeveloped power of these mountain streams is an important industrial asset. In Georgia and the Carolinas more than 100,000 horsepower has been developed and is being used by cotton mills alone, and public-service corporations in these three States are to-day developing 300,000 to 400,000 additional horsepower to turn the hundreds of mills and light the many towns and cities in the region. One of these power plants is shown in Plate I (opposite) and views of others are given in Plate XII, *A* and *B* (p. 36). In the operation of the power plants already constructed and in the financing and building of those yet to be developed the erosion problems of the region are becoming important factors, deserving serious consideration.

From the slopes along these streams a steadily increasing amount of waste is working its way down their channels, filling the dams and destroying their storage capacity; and this loss of storage means a decrease of efficiency that is calculated by the most experienced mill engineers to amount to 30 to 40 per cent in plants that have been built especially for storage and a somewhat less marked decrease in other plants, the exact amount depending on the topography of the basin and the regimen of the particular stream on which the plant is located. So universal is this silting of storage basins that a prominent mill engineer of wide experience in his reports on the construction of power plants no longer calculates on power or on anything except the flow of the stream, and he has increased his usual construction estimates by an allowance for increased storm waters that must be taken care of without endangering the dam or plant.

Experience has shown that storage basins constructed in this region in recent years are rapidly filled with sand and silt, through which the stream maintains a channel only large enough to carry the ordinary flow. On a few streams diversion dams without storage furnish the most economical development, but the dams at most of the cotton mills have been built to store water over night or over Sunday, and at one dam, at least, the original storage capacity was sufficient to hold a week's ordinary flow.

At one large plant storage basins that originally had capacity to hold the water accumulated by several days of ordinary stream flow have been so filled that they can not now hold even the flow of a single night. When the filling first began to cause serious trouble efforts were made to keep the material dredged out with centrifugal pumps, but the cost was soon found to be prohibitive. It has been necessary to maintain this dredging plant, however, in order to keep the channel to the wheel pits open.

At one dam where two years before, when the dam was first closed, there was a depth of 28 feet, an island had recently appeared. At another place, where a high dam had been built on a small stream, the pond has been so filled that its storage capacity has all been lost. At another place a pond in the Spartanburg region, cleared out by the bursting of a dam in the flood of June, 1903, and since rebuilt, was in 1905 again almost full of sand and silt. A pond about 4 miles long and 40 feet deep at the lower end was in four years entirely filled in its upper part and near the dam was three-fourths full. Another pond, seven-eighths of a mile long and 35 feet deep, filled within 300 feet of the intake gates in less than two years.

On one river eight dams were built within a few miles of one another. The upper pond soon filled with sand and clay; then the second; then the third; soon all the rest will be filled. The mills can then utilize only the unregulated stream flow. Auxiliary storage reservoirs built on the stream above the power plant have filled completely with sand and silt and are useless.

Wide ponds fill most rapidly because the current through them has less velocity. In other words, they act as settling basins. Long, narrow ponds fill less rapidly because of the greater velocity of current through them, and they scour out more during floods.

All the power plants recently built practically ignore storage and depend on the flow of the stream only. When sluicing out is attempted the stream cuts merely a vertical walled

channel down through the material and removes only enough for a channel way. The expense of dredging has been found to be prohibitive. The dredge merely keeps open the way to the wheel pits.

Another result of erosion is the greater frequency, greater suddenness, and greater height of the floods, since the run-off from bare washed slopes is more rapid than from wooded slopes. These floods endanger dams and property of all kinds within their reach. During a single year recently the flood loss in these southern mountains reached some $18,000,000, and during the succeeding year the loss was about $9,000,000 more.

Still another result is a change in the normal stream flow. When so large a proportion of the rainfall rushes at once into the streams and is carried away, a correspondingly smaller proportion is left to soak into the ground and feed the springs that sustain the stream flow during periods of no rainfall. The flow of the springs is weakened, and low water in the streams follows more rapidly after floods than it formerly did. The period of high water is shortened and made abnormally high; the period of low water is correspondingly lengthened and made abnormally low.

NATURE, EFFECTS, AND REMEDIES OF EROSION.

PROCESSES.

Erosion may conveniently be regarded as of two kinds. One kind occurs along streams as a result of either normal or flood flow and may be called stream erosion; the other kind occurs over all other parts of drainage basins and may be called general surface erosion.

In the humid regions stream erosion results from the activities of the perennial streams, large and small, and hence is a continuous process, though its effects vary greatly in intensity, being at a minimum during low-water stages of the streams and at a maximum during flood periods. Its work is restricted to that portion of the basin within reach of the flood waters, or, in other words, to the flood plain. Stream erosion involves the transportation of the eroded material and the deposition of much of it along the reaches of lower slope and lessened velocity. During a single great flood a stream may first cut great runways across its flood plain or dig great holes in it, and then, in later stages, deposit upon it a thick covering of sand and bowlders.

General surface erosion results from the complex interaction of a number of forces, chief among which are the various atmospheric agencies, producing rock disintegration and decomposition and preparing the material for removal, and the more active effect of the rainfall striking the ground. The steepness of the slope, the nature of the soil, and the forested or cleared condition of the surface are also direct factors. In the region under consideration the actual erosion or removal of surface materials is due almost entirely to the work of the rain as it gathers into rills and rushes down the surface slopes to join the permanent streams. General surface erosion is therefore most active in periods of rainfall, and might be regarded as an intermittent rather than as a continuous process. This view, of course, disregards the erosive activity of the wind, since it is unimportant in a region like the southern Appalachians, and the slow but more important creep of the surface material down the slopes, due to freezing and thawing and to the action of plants and animals.

During heavy rainfall a grass sod will absorb less water than a good humus cover in a forested area and run-off from the grass land will therefore be greater than from the forest, and flood heights in areas left in grass must show a corresponding increase.

EROSION IN FORESTED AREAS.

In forested areas general surface erosion is at a minimum. The force of the blow struck by the raindrops is lessened by the forest cover, and, indeed, very many of the drops do not strike the ground at all, but hit the litter of fallen leaves and twigs or the mat of moss or other low vegetation that completely carpets and conceals the soil surface. The forest soil is

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thus effectively protected from the blows of the raindrops that would cause the loose soil on the bare surface of a freshly plowed field to melt away like snow before a summer sun.

As the fallen drops gather to flow down the slope they are checked in their movement by the leaves and litter or they are absorbed by the spongy mass of soft moss or turf, so that very much of the rainfall flows slowly and gently down beneath the actual surface and within or through the matting of leaves and moss. The movement is so gentle that scarcely any soil particles are removed, and so slow that for hours after a rain has passed the soil covering is filled with water and even days later is still moist.

This protective effect of the forest cover was observed by the writer many times while he was at work in the region. Forested surfaces showed no signs of erosion; bare gullies or other indications of general surface or sheet wash were notably absent. The bottoms of the gullies in many forested areas were covered with leaves, soft vegetable mold, or moss, and the vegetation growing in them showed that though some material was being removed along their immediate courses, this removal was proceeding at an exceedingly slow rate. A small gully under these conditions is evidently the result of long years of erosive activity. Indeed, under conditions of a stable forest cover the gullies or channels for the removal of surface rainfall doubtless slowly assume a slope and width that are in adjustment with the usual intensity of rainfall, and when this adjustment is once established the woodland rain-water channels become stable and would change exceedingly little, perhaps, even in hundreds of years, were it not for an occasional cloud burst or storm of extraordinary intensity which furnishes them a volume of surface water with which their cross section and slope are not commensurate. At such times erosion takes place along their courses and holes may be gouged out that during succeeding years once more become clad with vegetation.

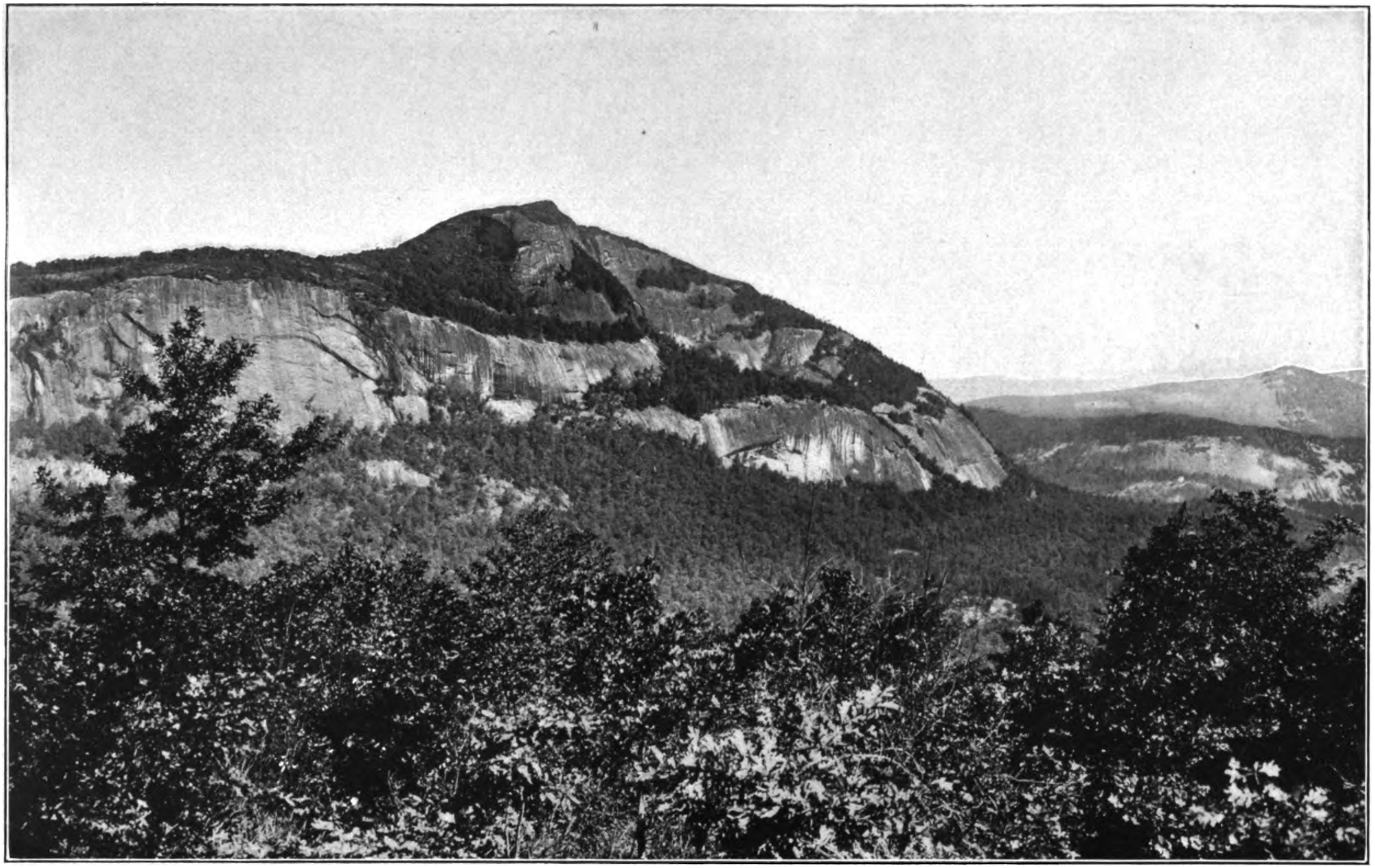
In the course of the long geologic ages that these southern Appalachians have been subjected to atmospheric erosion there has come about, in all but a very small part of the area, such an adjustment between the steepness of the forested slope and the average rainfall and other erosive agencies that the wasting of the slope is reduced to a minimum. In places where the surface may have once had excessive slope erosion was rapid and the slope was gradually reduced; with lowered slope erosive power decreased until the two were brought into harmony. The material prepared by disintegration and decomposition for erosion then became just equal to the removing capacity of the erosive agents, and somewhat later, with further decrease of slope and of erosive power, more loose material was furnished than could be removed and it began to accumulate and form a soil covering. This soil covering has continued to increase in most of the area until now it is many feet deep over much of the region and mantles and conceals the underlying hard rock from which it has been derived.

This long-continued process of adjustment between surface slope and erosive action has given these mountains the rounded contours and softened outlines that characterize the southern Appalachian landscape and constitute one of its chief charms. Jagged ridge crests have long since become rounded domes and vertical cliff faces have given place to the gently flowing outlines of graded, forest-clad slopes. Cliffs are rare and are due to some rapid change in rock texture or structure or to a situation especially favorable for stream erosion.

On these graded forested slopes the removal of the soil cover of disintegrated material is perhaps due more to soil creep than to direct surface erosion, and it is probable also that under such conditions soil creep reaches its maximum of efficiency as an agent of general surface reduction. Movement of the soil layer due to such creep is necessarily slow, does not result in producing bare earth or rock surfaces and is not attended with danger to the surface, the forests, or the future industrial development of the region.

Streams that flow from such forest-clad graded slopes show certain well-defined characteristics. During rains they rise more slowly than similar streams in cleared areas; they also continue longer in flood and fall to normal stages again more slowly because of the retardation of the surface run-off by the leaves and litter of the forest.

Such streams, even when highest, are, as a rule, only slightly discolored, and this discoloration is due largely to macerated leaf fragments and decaying organic matter and only to a very



SOUTHEAST FACE OF WHITESIDE MOUNTAIN, SHOWING ROUNDED PRECIPICES OF ROCK.

Much of the rock is bare and part of it is covered by a thin layer of soil held on the rock only by the mat of forest roots. See page 17.

slight extent to soil particles held in suspension. Some of the streams flowing from forested regions are perfectly clear, even when swollen by continued rains far beyond their normal size. Such, for example, are many of the streams in the Toxaway region, the headwaters of Pigeon River, the numerous small streams flowing from the Balsam and Great Smoky Mountains, the headwaters of Cane River flowing north from Mount Mitchell, and others that might be mentioned whose basins are unbroken forests.

Streams of this class carry almost no load of waste from the general surface of their basins and so are free to expend their energies in eroding materials from their bed and banks. Hence over all the territory examined such streams were generally found to have scoured their channels between steep and usually high banks, to be flowing over beds of cobbles and bowlders or across ledges of hard rock, and to have gouged out deep and quiet pools here and there in softer rock. Such stream channels change slowly. They are in stable equilibrium—an equilibrium or adjustment which would remain undisturbed for ages, during which the region would continue to waste away as slowly as in the past, were it not for the work of man in clearing the land and throwing out of equilibrium both the surface slopes and the stream gradients.

The removal of the forest brings the slopes that represent the adjustment of a forested surface to erosive agencies into unstable equilibrium, active erosion begins, the soil accumulated, it may be through centuries, is quickly swept down into the valleys, and the mountain side is left a scarred waste of bare rocks and bowlders. For such areas the only safety is the retention of the forest now there, for once removed neither the soil nor the forest cover can be replaced.

Bare rock surfaces are more numerous in granite or granite gneiss areas along the eastern face or scarp of the Blue Ridge than elsewhere in the southern Appalachians. Such, for example, are the surfaces of Table Rock, S. C., Mount Whiteside (Pl. II, p. 16), and numerous other bare, steeply domed or precipitous rock scarps, in the Highland-Toxaway region, in the Hickory Nut Gap region and at other places northward. Rock surfaces of the same type are also found in the upper Davidson River country and at a few places elsewhere in the region west of the Blue Ridge. These granitic rocks weather spheroidally, and wherever erosion produces very steep slopes the surface soil and underlying rotten rock tend to shell off and leave a bare domed or precipitous granite surface. In these particular areas, where this tendency is so strong that nature has not been able wholly to counteract it, it would be especially regrettable should man cut away the forests which, even when unhindered, are scarcely able to hold a soil covering, and thus permit the few feet of soil now overlying the granite or gneiss to be swept away, as it would be swept away in a few years after extensive clearing, down to the bare rock.

The effectiveness of such a thin root-matted soil layer in protecting steep surfaces from erosion may be observed when its continuity is once broken by the clearing of a field, the cutting of a road, or even the upturning of a tree. On the lower side of the break the turfed soil layer—it may be a foot or even less in thickness—may be seen to slip off bodily in avalanche fashion or to roll back from the bare granite like the bark when stripped from a tree.

Fortunately for the region, this spheroidal type of weathering, with its peculiarly disastrous consequences when erosion becomes active, is restricted almost entirely to granitic and gneissic rocks and even in them is not found in all types and under all conditions, so that a large part of the mountain region, where such rocks either are not found or do not possess the requisite texture or mineralogical character, is free from that particular danger.

Another type of forested area in which the soil cover is thin occurs in the belt of steeply tilted and folded quartzite and slate rocks found chiefly along the North Carolina-Tennessee line. These rocks disintegrate so slowly that a soil mantle sufficiently thick to conceal the rock nowhere forms, but the meager residual material lodges in the chance crevices and irregularities of the surface, between which bare jagged ledges project. On such areas the growth of trees and other vegetation is too scant to aid greatly in soil development. The projecting ledges, as well as the poverty of the soil itself, render the land useless for agriculture, and it can be

utilized only for the growth of such timber as it can support. The undergrowth is sparse, and during the summer the surface becomes very dry. These areas need guarding from forest fires and protection from deforestation.

Though forest tracts in the southern Appalachians are, under natural conditions, subjected to relatively little erosion, yet man's activities are causing destructive erosion. Much forest destruction may be caused by gullying attended by undercutting and caving (see pp. 19-20) starting in cleared areas and extending upward into higher forested areas. Where the slopes are too steep to be cleared, many of the more gently rounded crests are cleared as far down as possible, and the surface drainage from these ridge-crest clearings, gathering at the lower edges of the fields into a few channels, rushes down across the steep forested slopes below, excavating deep channels where otherwise the surface would remain unbroken.

A much more common and far more destructive cause of erosion in steep, forested slopes is the dragging of logs along the ground in lumbering. The logs quickly wear in the soft earth smooth grooves or trenches, which during rain are converted into chutes, down which the water rushes with great velocity, sweeping rocks and soil before it. The effects of this log dragging may be seen in the many runways opened through the forests and in the great amount of soil and loose rock swept down the slope and deposited as cones at the lower ends of the chutes on little flood plains or narrow stream channels. The principal injury is not usually confined to the lumbered area itself, though this becomes furrowed wherever logs have been dragged, but extends to the lands and property along the streams below, where the floods are increased in height and in destructive effect. These dragways exist wherever lumbering has been carried on, for few of the lumbermen have taken precaution to prevent this danger. Caring little for the land after the timber is removed, they feel neither moral nor legal responsibility for the condition of the lands and other property along the stream below.

EROSION ON CLEARED SLOPES.

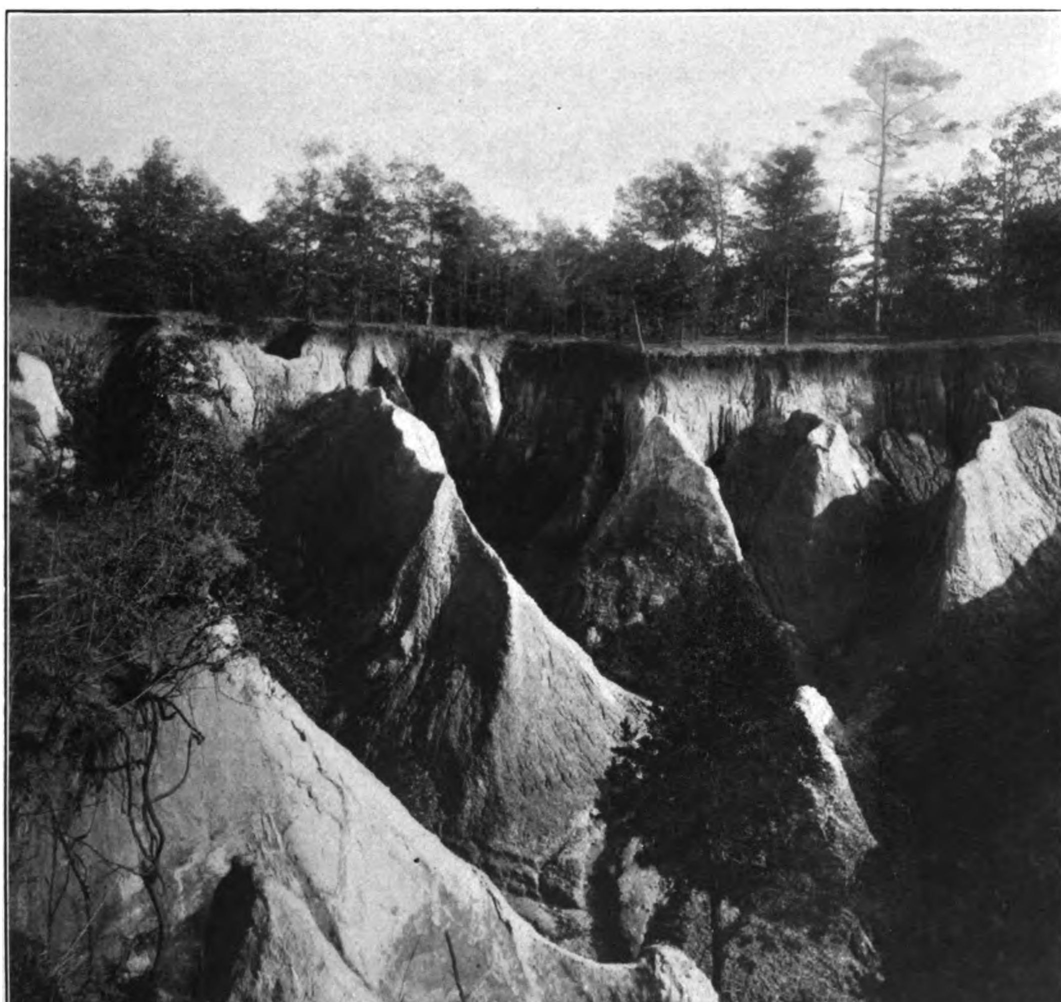
The clearing of graded forest-clad surfaces destroys the slowly reached adjustment between slope and erosive power and gives great impetus to erosion. In this erosion of cleared slopes the influence of the geology on the rate and the results of erosion becomes plainly apparent.

Other things being equal, the extent and character of the general surface erosion observed varies with the geology. It may be said that in a large measure geology controls erosion, for the nature of the rock determines the character of the soil, and variations in the character of the soil determine corresponding variations in the liability, manner, and rate of erosion. Two areas that are equally steep may when cleared differ greatly in character and rate of erosion. One may not erode at all; the other may erode rapidly down to the barren subsoil or the bare rocks.

In some parts of the region the soil on even the steepest cleared slopes was observed to be scarcely at all affected by erosion, although tilled year after year, and inspection usually verified the truth of the general reply to questions concerning erosion asked in such regions—"Our mountain-side fields do not wash away." It was found that such soils were permanently more or less loose and porous, and that their resistance to surface erosion varied directly with their porosity or permeability to rain water. A large proportion of the rainfall immediately soaked into the ground and found its way downward through underground channels; very little flowed off over the surface. Generally such resistant soils were also characterized by many small undisintegrated rock fragments, which aided both in keeping the soil open-textured and in checking the velocity of the downward-moving surface portion of the rainfall by opposing themselves as obstacles to its flow and causing it to drop many of the finer soil particles it might have started to carry. Certain schists and gneisses, especially the more siliceous types with mica and hornblende and those of nonhomogeneous grain, were the rocks found to weather most commonly into erosion-resisting soils. Some quartzites were also found to produce open-textured stony soils that did not erode badly. In general it may be said that a porous or a stony soil, whatever the type of rock from which it has originated, will be apt to resist general

A. INCIPIENT GULLYING OF SHOESTRING TYPE; BUNCOMBE COUNTY, N. C.

See page 19.



B. RAPID EROSION IN DEEPLY DECOMPOSED SOIL MANTLE NEAR MARION, N. C.

See page 20.

surface erosion more or less effectively. Such soils may be cleared and cultivated with safety, even when they slope at an angle that would be quickly destructive to all other types of upland soil examined in the region.

The aggregate area of such erosion-resisting soils, however, is not great when compared with the total area of the mountain country. By far the larger part of the region is underlain by rocks that weather into soil that is easily eroded when exposed on deforested slopes.

In some places it was found that the entire surface wore away slowly, each heavy rain removing a thin layer or sheet of material, so that the fertile soil layer gradually wore thin and poor and the field was at last abandoned as worn out. Erosion of this type, which may be called sheet-wash, occurs characteristically on close-grained, compact clay soils whose particles cling together firmly and do not readily yield to corrasion by flowing water, so that channels are not readily cut beneath the surface and undercutting and caving are not possible. Soils of this kind usually result from the weathering of the finer grained and more basic varieties of igneous rocks, such as diorites, diabase, and gabbro, and also from the weathering of fine clay shales that are free from mica particles. Sheet-wash erosion is so slow and gradual that some farmers fail to recognize it and believe that their soils have deteriorated through exhaustion of the fertility, whereas they have slowly and almost imperceptibly worn away to the subsoil. Such farmers, ignorant of the process by which ruin has been wrought, clear other fields and start anew the same destructive process.

One of the most common types of general surface erosion is that which is characterized by the formation of parallel gullies, and which occurs on slopes covered with clay soils, homogeneous in texture and somewhat softer and more loamy than those described in the preceding paragraph. Such soils result from the weathering of sandy shales or, more commonly, of granite or other crystalline rocks which contain considerable quartz but no mica. Certain schists also produce soils of the same texture. (See Pls. III, *A*, and XVII, *A*, pp. 18, 78.) In such soils erosion begins by producing innumerable small parallel gullies that extend straight up and down the slope and divide the surface into a minute fluting of sharp grooves and ridges. As these gullies deepen they become wider, and the smaller ones are encroached upon and obliterated by their larger, more active neighbors until, instead of a dozen or more in a yard's width, their number is reduced to one in a yard or one in a number of yards. Their bottoms are sharp, their sides steep and convex, and the tops of the divides between adjacent gullies, at first jagged, afterwards become rounded and sharply or broadly convex, the differences depending on differences in the soil texture and in the rate of vertical downcutting along the gully ways. (See Pl. XVII, *B*, p. 78.) Such systems of gullies concentrate the surface rainfall so that it works very efficiently as an agent of corrasion, and the process once started is very difficult to stop. The fields attacked are soon abandoned and left as scarred wastes while new ones are cleared.

Erosion of the parallel gully type occurs in many parts of the southern Appalachians. It is typically shown at Ducktown, Tenn. (Pls. XVI and XVII, p. 78), and near Balsam Gap, N. C., as well as at many other places.

Of all forms of general surface erosion, gullying, characterized by rapid downcutting accompanied by undercutting and caving, is most rapid in its progress and most difficult to check, as well as most spectacular in its appearance and most destructive in its effects. Erosion of this type occurs in soils underlain by a deep, relatively soft micaceous subsoil. Deeply decomposed material of this kind results from the weathering of micaceous and feldspathic schists—rocks that cover considerable areas in the region and determine the type of surface erosion wherever they occur. The surface in such areas may have weathered to a fairly compact clay soil that offers moderate resistance to erosion, and if the slope is gentle careful attention may keep this clay surface intact; if it is once broken through, however, a gully quickly develops in the soft subsoil, deepens easily by corrasion, and the soft and arkosic material on the sides is rapidly undermined and slips or caves in, leaving vertical or overhanging walls. The head of such a gully is commonly more or less amphitheater-shaped and is rapidly extended up the slope by headwater erosion, in which caving plays a prominent part. Into these gullies

many square yards of surface soil may cave during a single heavy rain, and as the decomposed micaceous and arkosic material in which such gullies grow is usually scores of feet in thickness they may become chasms of great depth and width. This type, which may be called chasm gullying, is illustrated in Plate III, *B*, page 18.

When begun in cleared land, chasm gullying may advance upward into a higher forested area and undermine and destroy even the largest trees. Once well started it is almost impossible to check.

Still another form of erosion in cleared areas originates in small landslides, which usually occur after the soil has been thoroughly saturated and softened during a period of prolonged rainfall.

On steep slopes the surface soil may begin moving of its own accord, either slipping bodily off in a mass or becoming so soft as to flow off, when once started, as a stream of soft mud. This change of soil into flowing mud is likely to take place where a small wet-weather spring on the steep hillside happens to occur in a certain kind of soil. More frequently, however, landslides are caused by the trampling of cattle on steep slopes after the soil has been softened by prolonged rain. One cow climbing up or down such a slope may cause a number of such landslides, each of which, when once started, usually grows both in width and in length until it becomes a great bare scar in the field.

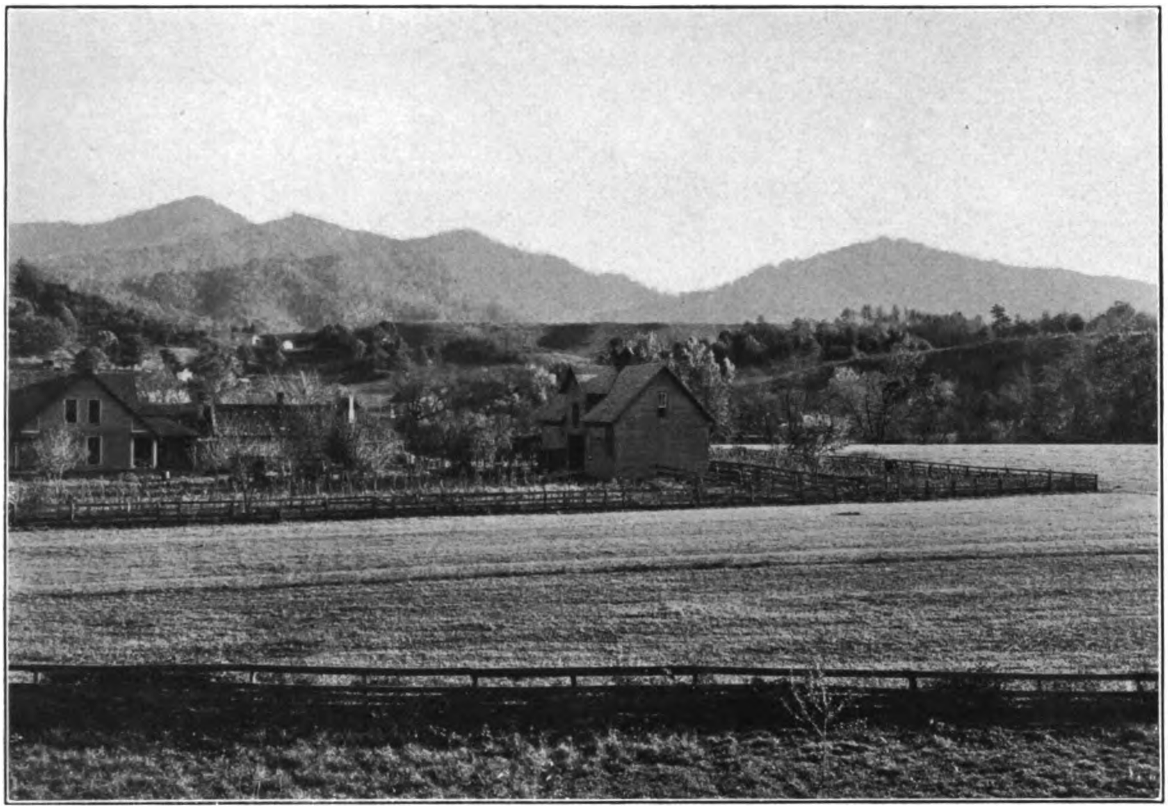
Landslides are likely to occur where the soil is micaceous or where it has resulted from the weathering of slickensided granitic or gneissose rocks. The slickensided surfaces are preserved in the weathered soil and when wet become planes of easy movement. Such surfaces aid greatly in the extensive caving that occurs in some areas where chasm gullying is the characteristic form of erosion. Landslides are also likely to occur where weathering of the exfoliation type has produced a sharp line or division plane between the soil cover and the underlying hard rock. In such places the soil layer easily slips off. Landslides of this type may occur in the forest, but, like those of the other types, are more common in cleared areas. During prolonged wet seasons it would be well to keep cattle or other animals off steep slopes that show any tendency to slide.

Level or nearly level upland areas may in themselves be comparatively safe from erosion, but they may nevertheless be affected by intimate relation with erosion, for water from areas lying still higher may erode channels across them, and the waste from such higher areas may cover their surface soil and destroy its fertility; or their own drainage, after being gathered into a few channels, may be shed upon still lower lands with the same effect as that produced by water received by them from the higher areas.

EROSION ON FLOOD PLAINS.

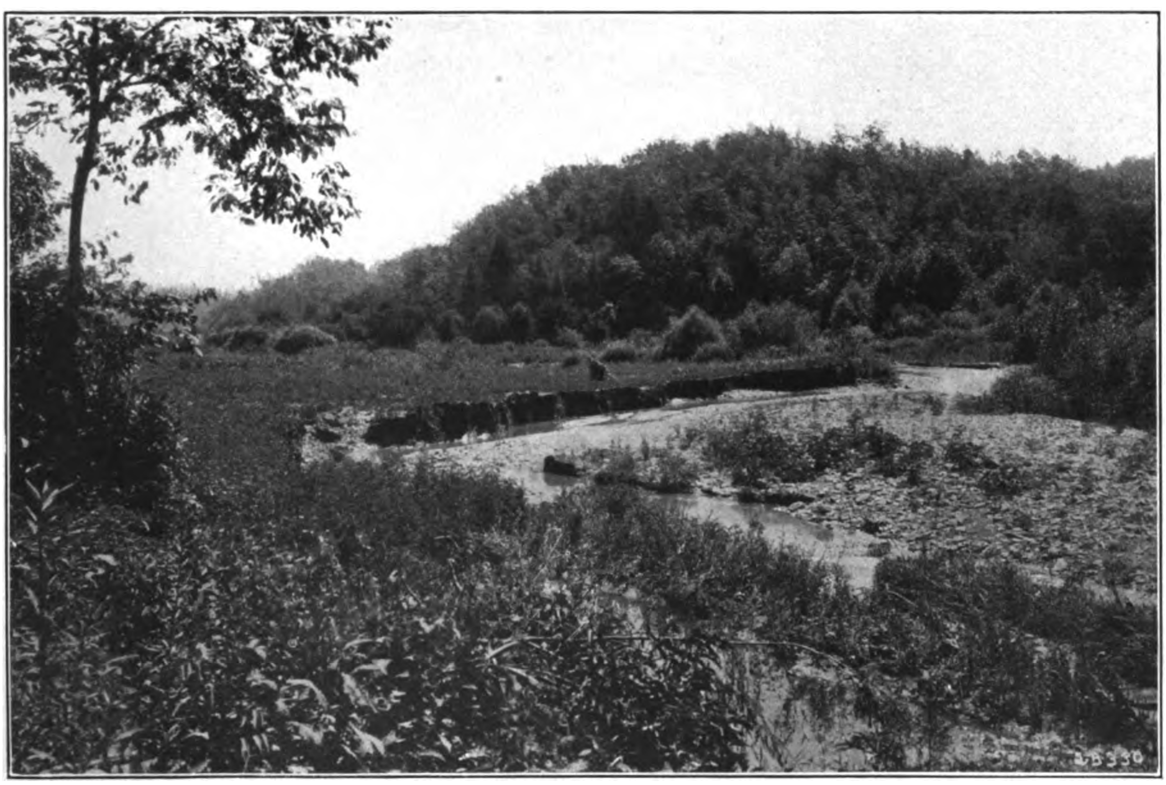
The typical mountain stream of this region flows so swiftly in its upper course that it sweeps away all loose material in its path and flows over bare rock, which it is actively eroding. Somewhat farther downstream, as its slope and consequently its velocity decreases, the stream reaches a point where, though still swift, it can no longer sweep away all loose material, so that the coarsest material begins to accumulate, making what may be called a bowldery or a cobbly torrent plain. As the current varies in velocity at flood and at low-water stages, this material is continually being reworked, and in the course of the cut and fill characterizing this reworking the stream, largely because of the heterogeneous nature and different sizes of the material, constantly shifts its position as it tears to pieces and rebuilds its torrent plain. The surface of such a plain fashioned by an impetuous current of greatly varying power is characteristically irregular or hummocky.

Farther downstream, as the velocity of the current decreases, the coarseness of the material composing the torrent plain and the irregularity of its surface correspondingly decrease. The tendency to lateral shifting of the channel also diminishes, but, if from any cause the stream be overloaded with waste and forced to deposit much of the waste in its channel, this channel filling deflects the current and the tendency to undercut one bank and build a cobbly or sandy



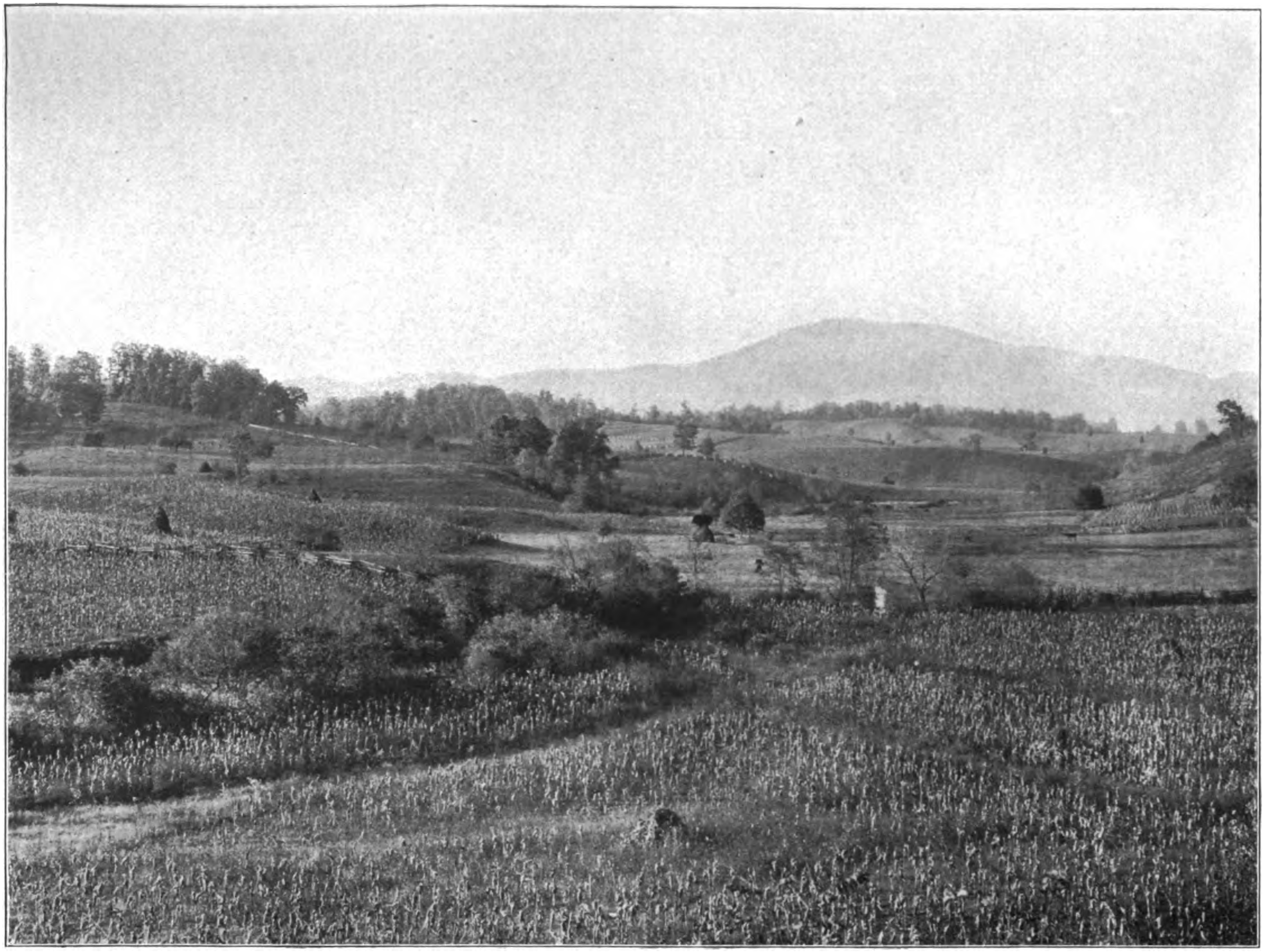
A. OLD AND NEW FLOOD PLAINS.

Extraordinary or possibly fossil flood plain in the foreground, with dwellings, and a high terrace or older fossil flood plain in the distance. See page 21.



B. STREAM WITH SHIFTING CHANNEL.

The stream is undercutting its flood plain on one side and building a cobble zone on the other. See page 21.



ASHEVILLE PLATEAU AS DEVELOPED IN PIGEON RIVER BASIN 2 MILES SOUTHEAST OF WAYNESVILLE.

waste zone on the other becomes strong. An example of such filling and cutting may be seen in Plate IV, *B*, page 20.

Still farther downstream the velocity of the current diminishes until the stream carries and builds into its flood plain only fine material, and the flood-plain surface then becomes a level surface, which still lower may build in the familiar way a higher portion parallel and near to the stream.

If the stream cuts down as it swings laterally, it develops on the side away from which it swings a sloping flood plain, which will here be called a beveled or hanging flood plain, the exact slope of which depends on the ratio of down cutting to lateral swing. Only the lower edge of such a flood plain is ever covered and damaged by floods.

If the stream is not overloaded with waste it normally develops a channel whose width and depth are proportioned to its volume, velocity, and flood height, and this channel usually has a sufficient capacity not only to carry away the ordinary flow of the stream, but also to carry a considerable volume of flood waters. With increase of flood volume in excess of the capacity of the channel the waters spread beyond the banks and flood an additional area on which deposits are laid down and a flood plain is built.

The inspection of many flood plains shows that they may generally be divided into two classes, the forms of one class commonly differing from those of the other in width and invariably in position and height and in the frequency with which they are covered with floods. The stream channel is usually bordered on one or both sides by a more or less narrow shelf cut in the flood-plain material and rising only a few feet above ordinary stream level. The exact height and width of this flood-plain shelf vary with the size and character of the stream. This shelf, or notch, is covered by the ordinary floods of the stream and may be called the ordinary flood plain. It may be only a rod or a few rods in width, even on a large river, or it may be much wider.

On the side away from the stream this ordinary flood-plain shelf is bordered by a scarp that is usually regular and well defined and separates a higher part of the flood plain from the lower one. The height of the scarp or the difference in level between the two flood plains varies greatly on different streams and even on different portions of the same stream, but on all streams this higher flood plain is reached and covered only at comparatively long intervals—measured perhaps by years—by floods of extraordinary height. The floods that now and then cover this extraordinary flood plain deposit sediment on it in some places and so build it up somewhat; but more commonly they scour runways across it and thus start subaerial erosion lines along which it is ultimately cut to pieces. Because of these scourways its surface is usually uneven. Deposition during the rare flood periods does not equal erosion during the long intervals between floods, and the plain soon shows signs of wasting away.

On many streams there are to be found above the level of this extraordinary flood plain more or less perfectly preserved portions of other, still older flood plains or terraces, whose height places them above the reach of even the highest floods. These may be called fossil flood plains to distinguish them from the ordinary and extraordinary flood plains, which may be spoken of as living flood plains. Such topographic features are so common and in many places so prominent along the streams, large and small, of the southern Appalachians that it has been thought best to define the terms, as their use in this paper will give conciseness to the description of flood plains. A view of an extraordinary flood plain is shown in Plate IV, *A*; fossil flood plains are seen in Plate IV, *A*, and Plate V, page 20.

The ordinary flood plain may have runways cut across it by floods or may be cut or gouged into holes wherever the flood current becomes deflected downward, as by pouring over a rock wall or other obstruction, or by forcing its way under logs that have lodged on it.

In other places the stream may be overloaded with waste and forced to drop a part of it until it fills its channel. It then flows here and there in irregular shifting meanders across its flood plain, depositing great quantities of waste and building up or aggrading the flood plain (see Pl. VI, *A*, p. 22). Such flood plains rapidly become useless for agriculture.

Elsewhere the flood may strip off the alluvial soil down to the underlying bowlders or the bare rock (Pl. VI, *B*), or it may be checked so as to deposit a bed of sand on the former flood-plain surface and convert it into a barren sand waste (Pl. VII, *A*). Under other conditions the covering spread over the flood plain may be of cobbles or even bowlders.

The channel of a stream that is not overloaded retains its normal depth, and the great increase in its depth during floods gives a channel prism so large that the stream can remove a much greater volume of water; moreover, the speed of the current, which is greatly accelerated by the increase in depth, is still so much slower on the outer edges than in the middle of the stream that it deposits on the flood plain the finer material that was carried in suspension and thus benefits instead of injures the adjacent lands over which it flows. The Chattooga, for example, which has an unusually swift current, its average slope being 28 feet per mile, frequently floods its bottoms at Russells, but instead of cutting them to pieces deposits sediment that enriches them. The upper Yadkin is another good example. It is enlarging its channel by scouring away its banks in order to handle more efficiently the steadily increasing volume of flood water it is now receiving.

The cobble zones scoured out along the main channels of many of the streams examined are the results of the effort of the streams to adjust themselves to changed conditions by providing themselves with auxiliary channels to carry off flood water. Where man's selfishness or shortsightedness or an unusual combination of circumstances make these efforts of the streams inadequate, disaster results. Where man has increased erosion so as to overburden the streams with waste and to force them to fill their channels he has foredoomed his lands to be cut to pieces by floods. Wherever from any cause flood heights have increased, fences, bridges, dams, mills and all other property, as well as human and other lives within reach of the water, are endangered and liable to be destroyed, as they have so often been destroyed in the southern Appalachians in the last decade.

On the other hand, in regions such as the basins of the Holston, the New, and the Monongahela, where man's agency in clearing the soil has not greatly accelerated the erosion of upland slopes, and so has not so increased the supply of waste furnished to the streams from these slopes as to fill the stream channels, but has chiefly hastened the movement of storm waters into the streams and so augmented flood heights, the damage wrought by the streams will consist not so much in tearing lands to pieces as in sweeping away all classes of property within reach of the flood. Where stream channels have been filled by the progress of erosion, as in most of the southern Appalachians, the disaster includes lands as well as property and life.

REMEDIES FOR EROSION ON SLOPES.

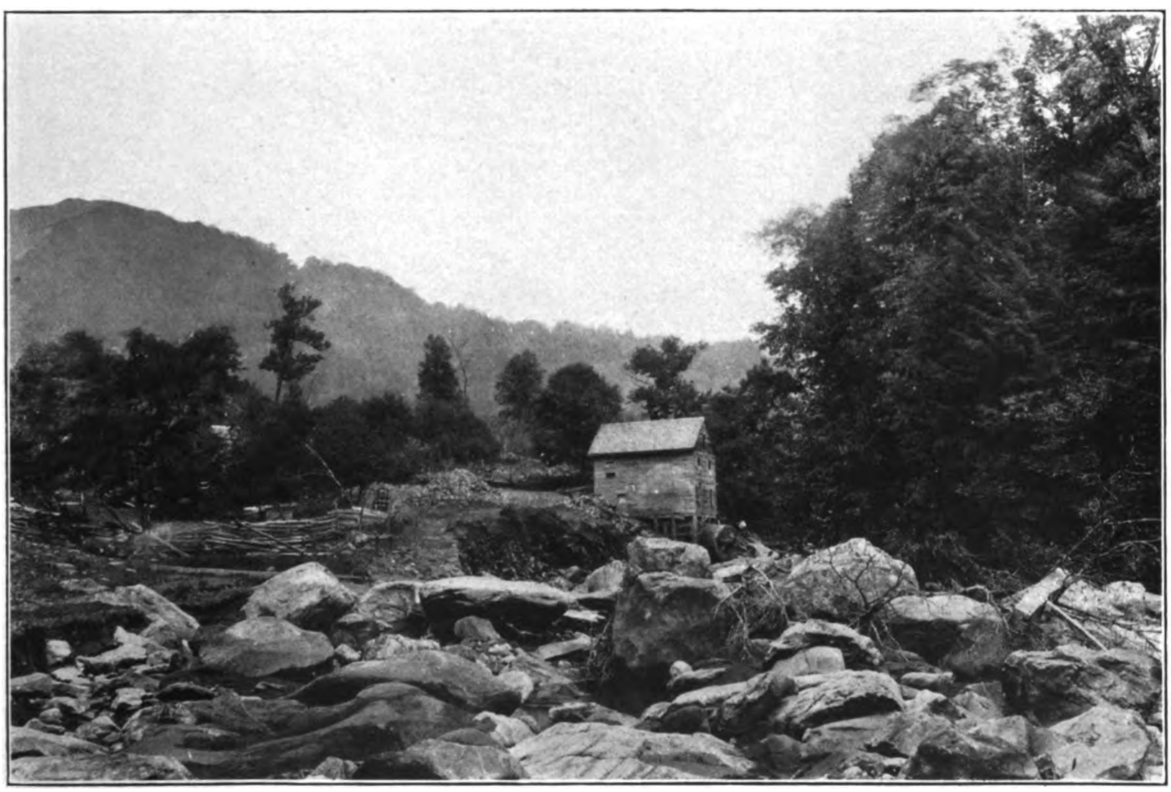
The most obvious method of preventing erosion is to prevent the clearing of the steep slopes. Just how steep a slope may safely be cleared is a problem to which there is no one solution. It has often been said that no slope steeper than 15° should ever be cleared, and this is probably as good a general statement as can be made. In some places, however, under certain conditions of soil texture and rainfall, slopes less than 15° erode badly; in others slopes of 20° or even more may be cultivated without serious danger of erosion, the secret of the immunity being in the texture of the soil. In regions where slopes of more than 30° were cultivated the author was frequently told that the lands did not erode, and this statement was largely confirmed by ocular evidence.

The allowable limit of steepness for cleared lands varies, then, with local conditions, but it may be said that almost everywhere throughout the southern Appalachians this allowable limit is exceeded, and in many places so greatly exceeded that rapid erosion of the cleared slopes is inevitable.

All cleared slopes should be thoroughly terraced if they are to be cultivated. Terraces can be so constructed that little or no water will flow from the terraced fields during even the hardest rains. In fields cultivated under these conditions there is no removal of soil particles and no filling of stream channels and resultant destruction of flood-plain lands. Terracing

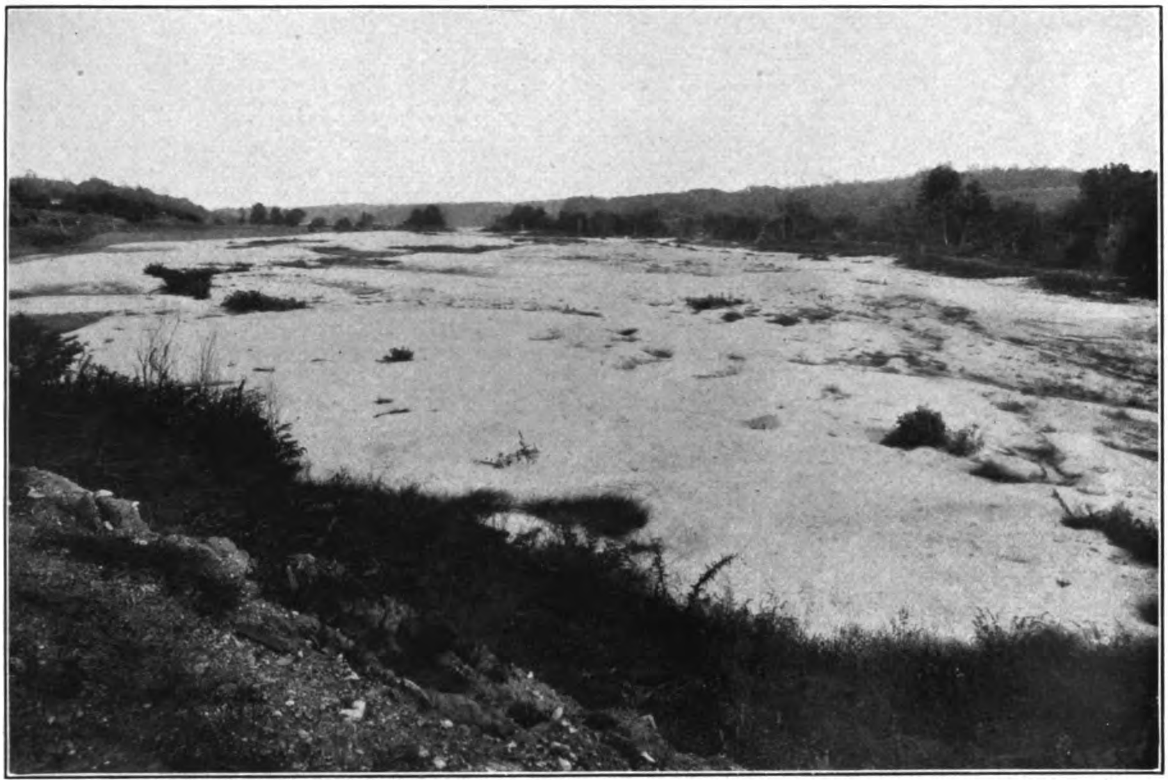
A. STREAM OVERBURDENED WITH WASTE AND AGGRADING.

See page 21.



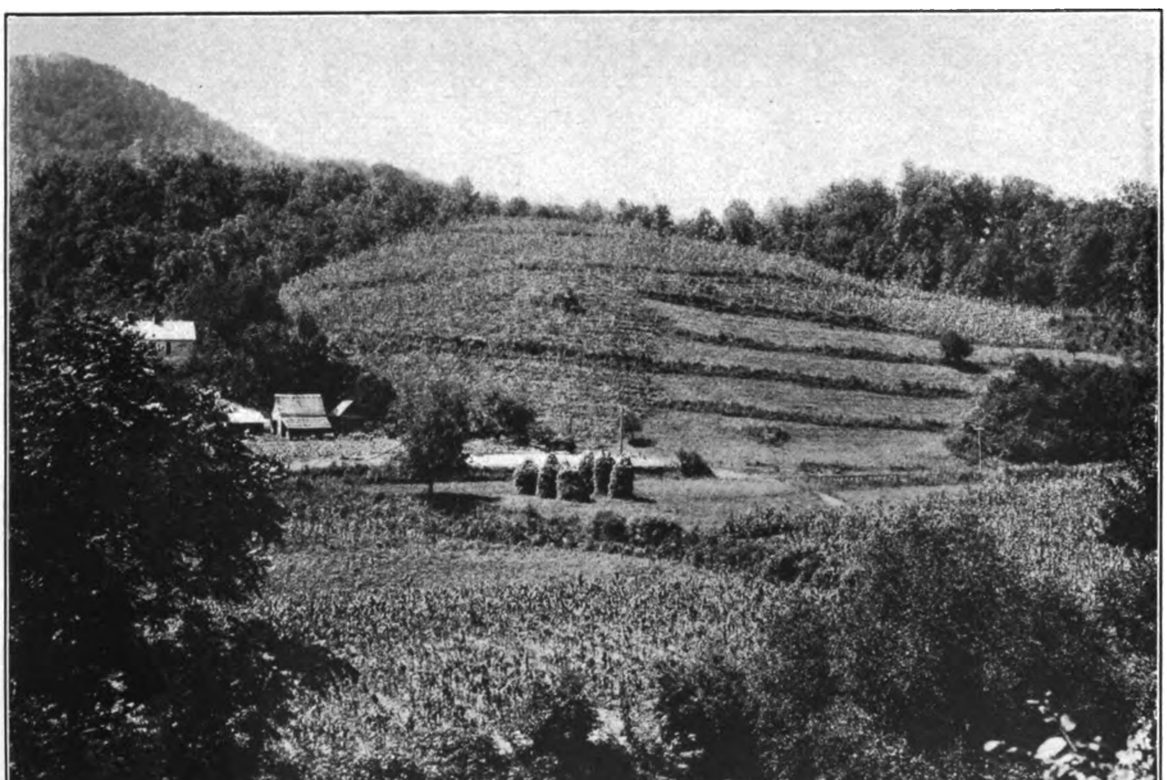
B. ALLUVIAL SOIL STRIPPED TO THE BOWLDERS.

See page 22.



A. LAND COVERED WITH SAND.

See pages 22, 45.



B. HILLSIDE TERRACED TO PREVENT EROSION.

See page 23.

can be far more generally practiced than it is all over the region examined and is necessary to insure a really safe system of agriculture. The best terraced region observed was in the Savannah River Basin, between Toccoa and Elberton, Ga. Good terracing was also noted about Greenville and elsewhere on the Piedmont in upper South Carolina. An example of crude but effective terracing is illustrated in Plate VII, *B* (p. 22).

Grass will effectually prevent erosion after the sod has once become well established. The farther south one goes, however, in the southern Appalachians, the more difficult it is to obtain and keep a good sod. In the Watauga and New River basins it is easy to protect the lands by grass, but on the Chattahoochee, in northern Georgia, it would be much more difficult, because the elevation there is much lower and the climate is therefore dryer and hotter and less favorable to the growth of grass.

If erosion has already occurred on steep slopes one of the best remedies, if conditions have not become too bad, is to cover the surface with straw, leaves, or forest litter, and over this cover to place brush to hold it in place. This mechanically protects the soil, much as does the humus cover in the forest itself, and holds it until plant growth has again taken possession and arrested rapid erosion. Except in a few places where the soil is exceedingly poor, weeds and briars will now spring up rapidly and will be followed in a short while by wind-sown tree seedlings that will start the new forest growth on the denuded slope. Natural reforestation in the southern Appalachians is usually rapid, but if for any reason it is desired to hasten it or to control more closely the kind of growth, artificial reforestation is easy, though of course this is more expensive than natural reforestation.

Where deep gullies have once started log or rock dams may be used to prevent their further growth and to catch material with which to fill them. The use of such dams is not always advisable, since the water tends to work beneath them and thus to concentrate and increase the vertical scour. Moreover, they become in themselves mechanical obstructions that may interfere with the subsequent use of the land for agriculture. If used they should be faced on the upper side with brush or straw to prevent the water from working through them. If thus made tight they soon become filled with the material that is being carried down the hillside, and the former gully or inclined trench is converted into a series of terraced steps. For a view of brush dams used to check erosion see Plate VIII, *A* (p. 24).

In places where the slope is not too great and the cutting has been shallow, gullies may be filled with straw so as to catch the sand and clay that is being removed. This device affords an effective remedy for gullies and has the added virtue of not leaving mechanical incumbrances on the reclaimed area.

Erosion may be checked by preventing the fires that usually follow in the wake of the lumberman and by guarding against the formation of erosion chutes by the dragging of logs down steep slopes. The mere removal of the mature forest itself need in no wise affect erosion or flood problems in a region like the southern Appalachians, where, if unhindered, the natural reproduction of the forest is rapid. In a few years the new growth makes an even denser cover of trunks, branches, and root mattings than the old, and protects the soil at least as effectually.

REMEDIES FOR EROSION ON FLOOD PLAINS.

On flood-plain areas the most important thing that can be done to the area itself to prevent erosion and flood damages is to maintain by all possible means a deep, straight channel for the rapid removal of flood waters and waste. The removal of obstructions and the straightening of the channels of small streams aid greatly in scouring out and improving the channels and hastening the run-off. Means of regulating and confining the shifting channel of a wild mountain torrent are widely used in Europe, but practically unknown in America. Retaining walls of stone or rock-filled cribs serve this purpose wherever the interstices may become filled with fine material and so closed to the free passage of water through the wall. Where such filling is impracticable a facing of sheet piling may answer the purpose. A rough rock-filled

log crib used for restraining such a stream is illustrated in Plate VIII, *B*. In Europe the bottom and sides of some such channels are paved with stone, and dams or sills of rock are built at short intervals across the stream.

Another protection to banks that are being cut by streams that do not tend to shift so rapidly as torrents is to plant willow, aspen, balm of Gilead, or other easily propagated trees of rapid growth along the banks and over the entire denuded area. In starting such growth it is usually sufficient to plant small branches or sections of limbs at short intervals in the moist earth; they root readily and grow rapidly. The balm of Gilead throws up many shoots from its ramifying rootlets and soon makes an efficient bank protection.

In places protection may be had by building levees, but these are so expensive that their construction is warranted only when the lands or property to be protected are of considerable area and value. Lands that have been badly cut to pieces by floods, such as those illustrated in Plate IX, *A*, or deeply buried beneath sand (see Pl. VII, *A*, p. 22) or beneath gravel or cobbles, can usually be put to little or no immediate use. There is more ultimate hope of reclaiming lands that have been cut to pieces than those that have been buried beneath sand or stone, since later floods of less height may deposit material in the eroded places and in time may heal the scars and restore to use the once ruined land. A flood channel that is once established, however, is likely to be occupied by subsequent floods and to become a permanent flood runway. Planting trees and building walls across it may protect it and permit it to fill, but if the surface has been covered by stony or sandy waste there is little hope that it can soon be recovered.

In most places in the southern Appalachians both cutting and filling tend rather to grow worse than to improve by subsequent changes, since they have been started by floods whose tendency for a number of years has been to become gradually worse, because of the constant extension of clearing and of erosion on slopes that should have remained forested.

Now and then it is suggested that impounding reservoirs may be built with capacity sufficient to hold the flood waters, but this scheme is generally impracticable because of the great size and the cost of the necessary dams and the large area of land that would be submerged and rendered useless, as well as the danger that the dams might break and destroy life and property below. Furthermore, on many of our southern streams such reservoirs would become filled with sand and silt in a decade or two, as a number of private power dams in the Piedmont region of the South already have been filled.

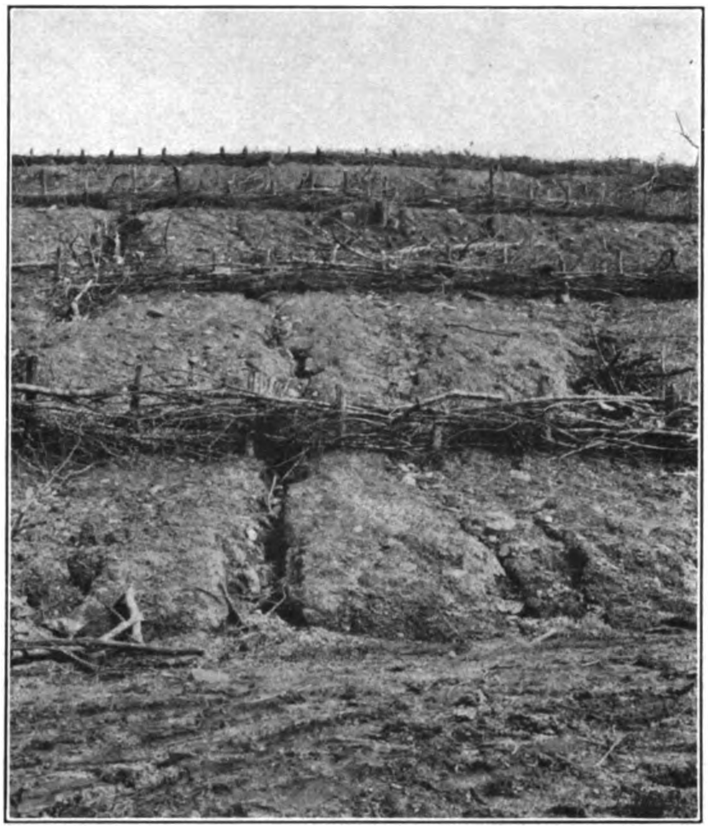
Far the most efficient reservoir for impounding flood waters is a good forest humus over the steep slopes of the stream basins. The only thorough means to check and prevent the destruction now going on in the Appalachian region from erosion, floods, and droughts is to maintain such a humus cover where it already exists and to replace it where it has been destroyed.

EROSION AT DUCKTOWN, TENN.

In discussing processes that vary in the character or intensity of their effects, it is well, if possible, to show the limits of the variation. A most notable example of the ultimate limit or extent to which erosion may go in the area under consideration is furnished by the Ducktown copper region, in the extreme southeast corner of Tennessee.

This region is an old peneplain that has been uplifted some 1,600 feet above sea level and has since been cut by stream erosion into a series of ridges separated by narrow valleys. The crests of the ridges are gently rounded, but their sides slope more steeply, and near the base become in places almost precipitous. The rocks of the region are deeply decomposed schists, which have yielded the heavy soil to which the rounded surface slopes are due. Only here and there are the schists exposed in bare ledges and these exposures are as a rule small. The dissecting streamlets formerly flowed in relatively narrow valleys and were actively eroding the rock ledges across their paths, depositing along their courses little or no waste.

The annual rainfall in the Ducktown region is between 50 and 60 inches and is often torrential. During the downpours soil surfaces almost literally melt away. Copper is mined and

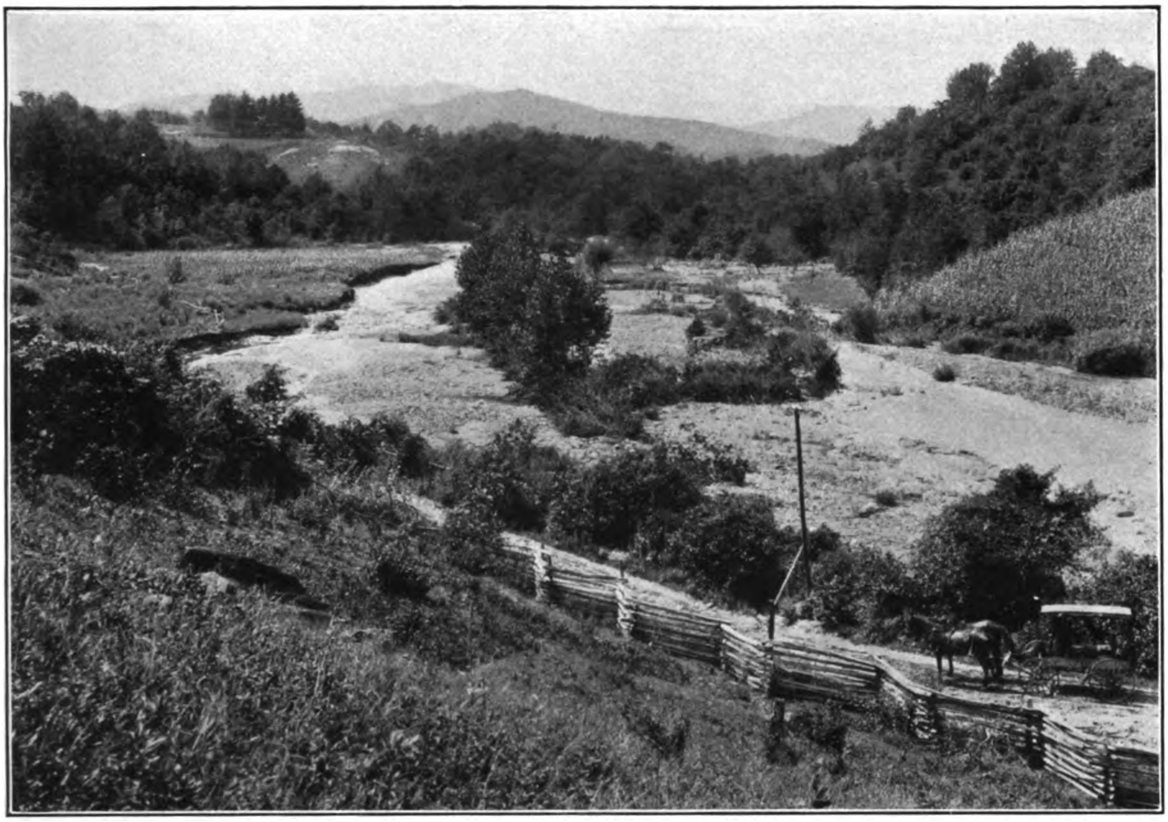


A. BRUSH DAMS BUILT TO CHECK EROSION.

See pages 23, 24, 25.

B. COBBLE ZONE AND LOG TRAINING WALL.

See page 24.



A. ALLUVIAL BOTTOM WASHED AWAY BY FLOODS.

The stream on the right, at the foot of the hill, formerly flowed to the left of the sycamores in the center of the picture. See page 24.

B. PART OF CATAWBA VALLEY NOT INJURED BY FLOODS.

See page 112.

smelted in the region on an extensive scale, and the sulphuric-acid fumes from the smelters have in the last few years killed all vegetation in an area a number of square miles in extent. In the short time since this was done erosion has deeply scarred the hills with gullies and the eroded material from these slopes has overloaded the streams and rapidly built waste plains of sand and silt along them. In places the soil has been entirely removed from these slopes and the bare red clay exposed, and in a few years the surface will be worn down to the underlying rock. Any small flood plain that may have previously existed along the streams has been buried beneath the rapid accumulation of waste from the hillsides, so that both hill slope and flood plain have been destroyed, the one by erosion and the other by sedimentation or aggradation.

Very little of the rainfall now soaks into the ground to feed the springs and they show the result of the change by their greatly diminished flow during dry seasons. Wells also go dry more often than formerly. A better idea of present conditions in this region may be obtained from the views in Plates XVI and XVII (p. 78) than from a number of pages of description. A more detailed statement concerning processes and results around Ducktown will be found on pages 77–79.

The result of erosion in the Ducktown region may be looked upon as the goal to which all erosion in the southern Appalachians is tending. If elsewhere in these southern mountains the cover of vegetation be removed as completely as at Ducktown, the rapid erosion that has wrought the destruction seen there may confidently be expected to follow, and with like results.

CHANGES IN STREAM REGIMEN.

Wherever mountain stream basins in the southern Appalachians have been extensively cleared the regimen or normal habit of flow of the streams has been changed. This change is believed to be due chiefly to increased erosion and consequent increased rapidity of run-off.

In the natural forested state comparatively little rock waste is furnished to the mountain streams, which therefore expend their energies largely in eroding their beds and cutting deep channels, such as may be seen in the Great Smokies, much of the Pisgah Range, or any other well-wooded part of the mountains. These deep, steep-sided stream channels are very effective in removing flood waters, and it takes considerable rain to fill them higher than their banks and produce a flood. They are amply able, even in flood, to carry away at once all the waste material furnished to them.

The removal of the forest on steep slopes generally increases the tendency to erosion. This increase may be very slight if the land is kept well sodded or if the soil is of a certain porous or stony type, but in a region like the southern Appalachians, with its deep soil and abundant, often torrential, rainfall, erosion is generally more rapid—it may be very much more rapid—on cleared than on forested slopes.

Erosion once begun, as a rule, soon develops gullies that furnish so much sand, clay, and cobble to the streams that they become overloaded and are unable to carry away all the waste that is brought to them. The excess waste is therefore deposited first in the channel, until that is practically filled, and then over the alluvial flood plain, which is thus converted into a barren waste of sand or loose stones. Such a sand-covered flood plain is illustrated in Plate VII, *A* (p. 22). The waste then begins working downstream, filling dams and pools as it goes, and soon gets down into the navigable parts of the great river systems, such as the Tennessee, making more difficult the problem of maintaining navigable channels. This condition may be readily understood by examining the Tennessee at low water and studying the growth of its sand, gravel, and bowlder bars and of its towheads and islands, and also by comparing the detailed reports made annually by the Army engineers concerning the improvements made by them in the open channel of the river. The knowledge gained by personal examination of the river adds much significance to the statements found in these reports. Some of the most notable changes on the Tennessee will be described briefly in connection with the general characteristics of this river on pages 79–83.

The waste filling a mountain stream causes an immediate change in the frequency and height of floods. When, under normal forested conditions, the channel is deep, a heavy rainfall is necessary to raise the stream to the bank-full stage; when the channel has become well-nigh filled with eroded material much less rainfall will put the stream out of its banks and cause a flood—in other words, floods will become more frequent.

The channel filling has another important effect. The same amount of rainfall will necessarily cause a higher flood when the channel is filled or partially filled with eroded material than when it was free from it, partly because the capacity of the channel to hold water is diminished, but more especially because the filled channel is not so efficient an agent for the rapid removal of flood waters. They pile up, as it were, and rise higher than before. Their height is further increased by the fact that the gullies on the eroded slopes and the bare surface of the cleared land deliver the storm waters to the streams almost as rapidly as they would flow from house tops or along city gutters. This rapid delivery of the storm water from the steep cleared slopes aids greatly in raising floods to abnormal heights. In other words, floods in steep, denuded, and eroded basins assume much the character of floods caused by cloudbursts, not only in their very rapid rise and great velocity, but also in their destructive violence and rapid decline to ordinary stages. Their height and velocity are increased and their length is diminished as compared with floods in the same stream when the stream basin was forested.

It might be thought that as rivers are but the sum or aggregate of their tributaries they will rise to the same height during floods and become correspondingly low during droughts. This, however, could be true only if stages of stream height varied synchronously on all the tributaries, and if all these tributaries were so adjusted as to position, length, and slope that they discharged into the main stream their abnormally high or low flows at the same time These conditions, however, are manifestly impossible in any large river system whose headwaters include areas that are diverse in geography and climate. Some tributaries may be in flood when others carry little water; some are long and of gentle slope, others are short and of abrupt descent. The river into which they flow represents, then, not the sum of their extremes, but more nearly their mean, and in its phenomena of flow will tend to preserve a mean.

The general variations in rainfall in all parts of any large river basin in the Appalachians are probably similar in kind though not exactly synchronous or of equal amount everywhere throughout the basin. The period of maximum rainfall, for instance, in this entire region usually occurs late in the winter or early in the spring, and the period of minimum rainfall late in the summer and autumn. The average stages of the small and large streams of the region vary in a general way in harmony with the rainfall, and just as the tributaries become, on the average, lowest late in the summer and fall, the main stream into which they flow becomes lowest then also, but this is a mean low, not an extreme low. In the same way the main stream is highest when the tributaries are highest.

It is probable that within recent years the mean low-water flow has been decreased on main streams whose tributary basins have been largely cleared. In the same way, the mean high-water stages of these streams have probably been similarly increased by excessive clearing. By this increase in high-water stages a larger proportion of the total rainfall is immediately carried away as run-off, and consequently a smaller proportion is left to supply evaporation and maintain the flow of springs and other ground waters. Evaporation in cleared and cultivated areas is at least as great as in forested areas, and as the average annual rainfall has probably remained unaffected by the clearing of the forest, the increased run-off must constantly leave a decreased supply for the springs, which must therefore suffer partial or total failure during prolonged drought.

Occasionally it is maintained that in any large river system the flow during low-water stages is kept up by the run-off from frequent rain storms on small areas scattered here and there over the basin, and that the river is consequently not dependent on the flow of the springs or ground water for its maintenance. The failure of springs, it is argued, would consequently

not materially affect the flow of the main stream of the basin, though it is admitted they would stop the flow of the streamlets to which they ordinarily give rise.

Local thunderstorms that involve considerable precipitation in small areas may, in times of general drought, contribute somewhat to the maintenance of the stream's flow, but these local storms are probably not so frequent in any particular large river basin as to maintain by themselves or even to nearly maintain the low-water flow of the main stream. In a basin like the upper Ohio, for instance, many days at a time will often elapse during prolonged dry seasons without the occurrence of enough local thunderstorms anywhere in the basin to affect materially the extreme low-water discharge of the river, and during some droughts in the Ohio basin there are so many days or even weeks together during which no rain falls anywhere within the entire basin that if the streams depended during such periods on the local thunder showers alone, the last water thus falling would have ample time to flow down the entire length of the river and out at its mouth and leave its bed entirely dry before another local shower would occur. The low-water flow of a stream during droughts depends very largely or almost entirely on springs and other ground water within its basin, and as they fail it will fail.

It has been suggested that, assuming that there has been no climatic change, and that rainfall is as heavy and thunderstorms are as frequent in forested as in deforested areas, it should be obvious that the discharge of springs plus the run-off in forested areas would exceed the run-off from thunderstorms alone in deforested areas and that of two streams the one from the forested area would show the larger flow.

It would be interesting to compile records of rainfall at all possible stations in, say, the upper Ohio basin, and ascertain as accurately as possible how often and in what areas local rainfall occurs during a general dry season throughout the basin, and thus test the matter so far as records would afford a test.

The streams of the southern Appalachian Mountain region furnish many illustrations of the various phases of the change of regimen outlined in preceding pages and leave no doubt in the writer's mind that floods are now more frequent, rise higher, move downstream more rapidly, and are sooner succeeded by low water, and that this becomes lower and lasts longer than formerly. The writer contends that the belief that these changes have occurred rests on so large a body of observed facts that it can not be successfully controverted.

Rainfall records and flood-gage readings are often appealed to by those who discuss the effect of forests on stream flow or those who attempt to determine whether or not changes have occurred in the regimen of streams, but each great flood is primarily the result of unusual rainfall, and many variable factors combine to determine the height to which a flood will rise at a given place or the height that will be reached by different floods.

Gage readings and rainfall records are not necessary to prove change of stream regimen, nor would their failure to show an absolute increase in flood heights at any given point disprove it, since some of these readings and records are subject to error and are inexact.

The discharge of a river can not be determined by and does not vary with the gage heights alone, for the velocity of the current is also an essential factor in the determination, and this velocity, though varying in certain respects with the depth of the current as shown by the gage height, also varies independently of the gage height—that is, it depends on the steepness of surface slope of the advancing flood wave. A flood of more sudden rise and consequently steeper front slope at the same gage height will have greater velocity and will discharge much more water than a flood of slow rise but of the same height. For the same reason the front part of any flood wave has a greater velocity than the hinder part, and hence as the wave advances downstream its length increases and its height and velocity diminish independently of any changes in width or slope of the stream channel. On this account floods in the lower part of a river rise more slowly, reach less heights, and subside more slowly than those in the upper part of the same stream. Humphreys and Abbot state, for instance, that in the flood of 1858 the Mississippi at Columbus, Ky., discharged more than 56 per cent more water at the 37-foot stage as the flood rose than it did at the same stage of the same flood as the river fell.

In a rapidly rising flood the transverse profile of the water surface is convex, being highest near the center or at the point of greatest velocity, and readings taken from gages near midstream give too great a cross section, while those near the bank give too small a cross section. Unless the river bottom is bare rock the cross section may vary rapidly during floods because of scour and fill and thus introduce additional sources of error in calculating discharge.

If a gage is situated a short distance below an important tributary, its flood records when there is heavy rainfall in the basin of this tributary will show abnormalities due to the superimposition of the floods of this tributary on the more general flood of the main stream. Such locally superimposed flood waves will usually disappear farther downstream. This or other local and ephemeral factors play parts that are so important in determining the heights of floods at given points that a series of gages situated at intervals along the same stream will not give proportionately high records of a series of floods. The flood giving the highest record at any one gage usually fails to give the highest record at any other of the series. A 40-foot stage, for instance, at one gage may at the next gage make at one time a 20-foot stage, at another a 30-foot stage, and at another some other stage. When one attempts, then, to tabulate flood stages on a river his results for the same series of years will vary according to the gage station he selects. This is well shown by comparing for a series of years the highest gage reading of the year on Tennessee River at Chattanooga and at Florence. In 1867 a stage of 58.6 feet at Chattanooga corresponded to a stage of 31.1 feet at Florence, whereas in 1897 a stage of only 37.9 feet at Chattanooga corresponded to one of 32.2 feet at Florence, and in 1901 a 37.4-foot stage at Chattanooga was synchronous with only an 18.8-foot stage at Florence. These differences are doubtless due partly to differences in the velocity of the flood wave and partly to differences in rainfall in the intervening part of the river basin. One who contends that floods on the Tennessee have increased in absolute height in recent years would find one of these stations better suited to his purpose than another, whereas some other station would be selected by his opponent.

Conclusions as to stream regimen that are drawn from tables of mean monthly and annual stages of a river at a given point, and that show nothing of the range of the variable heights that produce them, are worthless to show change of regimen. An average monthly stage at a given point might be compiled at one time from gage readings that at no time during that month varied a foot from the monthly mean, whereas at another time they might be the average during the month of numerous variations of wide range on either side of the mean. The mean tells nothing of the actual daily regimen of the river and is worthless to prove that there either has or has not been a change in this regimen.

The writer, indeed, believes that the mean annual discharge—not the mean gage height—of a river at any given point does not vary for a long series of years except as rainfall varies, but that if the region were deforested during the time the distribution of this mean discharge during the year would be affected unless the rainfall were distributed uniformly through the year.

The unreliability of conclusions as to stream discharge that are reached by considering gage heights alone is further illustrated by the fact that where large storage reservoirs, like those at the head of the Mississippi, for instance, are used to supplement the extreme natural low-water flow, their effect in raising the level of the water diminishes downstream and is sometimes entirely lost within a comparatively short distance; so that although the volume of water flowing past a given point is undoubtedly increased by the discharge from the reservoir, the fact is not shown by a notable increase in the gage height. Although the artificial reservoirs at the head of the Mississippi are said to raise the low-water level an average of 14 inches at St. Paul, Minn., their effect steadily diminishes as the river becomes wider and finally disappears entirely 51 miles below St. Paul.

Increased flood heights and flood frequency are most evident on the headwaters and not down on the navigable middle and lower reaches of a large river system, and the chief destructive effect occurs both along the headwaters and at points where the streams first leave the mountains and run out upon the plains. It was in and above Pittsburg, for instance, and

not down at Louisville or Cairo that the flood of 1907 on the Ohio was most destructive. It was at Elizabethton on the Watauga and at other places similarly situated on other Appalachian mountain tributaries of the Tennessee, and not down at Chattanooga, Florence, or Paducah, that the floods of 1901 and 1902 on that river were most destructive.

So far as the navigable portions of any of the larger river systems are concerned, the effects of erosion in filling stream channels with sand, gravel, and bowlders are of more importance than the increased height of floods. The increased frequency of floods on the navigable portions of streams is, however, of greater importance than increased height, since floods many feet lower than the highest floods known are able to destroy crops, and their increased frequency makes farming more hazardous on flood plains and decreases greatly the value of such lands.

There is abundant evidence on rivers such as the Tennessee of increased silting in the navigable portions of streams because of the increased erosion resulting from deforestation.

The various factors that regulate stream-flow and regimen may be classified under five heads—climate, topography, geology, vegetation, and artificial control. Since the effect of each of these factors can not as a rule be sharply distinguished, it is difficult to determine their relative magnitude, so that only their general tendency can be considered.

Many of those who have discussed the effect of forests on stream regimen have been disposed to consider one class of data or one group of conditions and to overlook others. Gage heights, for example, have been commonly used in presenting arguments for and against the effect of deforestation on stream regimen, without proper regard for the conditions that have caused the gage heights. Therefore, some of the deductions drawn from gage heights in regard to the effect of deforestation have been unwarranted and misleading.

The writer, though considering the various conditions affecting change of regimen, has based his conclusions chiefly on the record made during long ages in the flood plains, the slopes, and other features of the valley floors and sides.

Flood-plain deposits built up during long ages reveal the character of the floods by which they were formed. If the floods have been small or gentle the deposits will consist of fine alluvium; if they have been great or violent, the deposits in a region like the southern Appalachians will be coarser and will consist of sands, cobbles, or bowlders. If, then, the sands, cobbles, and bowlders that have been repeatedly strewn over their flood plains in the last decade by such rivers as the Watauga, the Doe, the Nolichucky, the French Broad, the Catawba, the Yadkin, and other southern rivers had been the kind of material those rivers had for ages been accustomed to deposit, their entire flood plains would be formed of such coarse material, instead of being composed, as they generally are, of fine sandy loam or clay. Had they at any time in the past been accustomed to carry material so coarse and built it into their flood plains, that material would be there to-day as a mute witness of the fact. Moreover, the normal change in the regimen of a river as the ages pass causes its flood-plain deposits to grow constantly finer. In these rivers, however, this process has been reversed; their deposits have recently grown coarser because there has been a recent increase in the height, velocity, and power of their floods.

This anomalous change in the regimen of these rivers is not due to any change of climate nor to any earth warping or other crustal movement. It is not due to the drainage of swamps and ponds, for these do not exist in the region. It is not due to road building, paving, or ditching, nor to the building of levees or dams or other engineering works, for such changes in the region are quantitatively insufficient to produce the results noted. It is, therefore, reasonably believed to be due to the denudation of the steep mountain slopes and their consequent erosion.

It is difficult to fix any definite period as the beginning of the change recorded, since it was more or less gradual and was not synchronous in all parts of the mountains. In general terms, however, the period extending from 1885 to 1890 may be taken as the start, for it witnessed the revival of industrial activity after the long period of exhaustion and slow recuperation that followed the Civil War. Railroad building then became more active; lumbering

began to be an important industry; agriculture was stimulated, tobacco especially in some mountain sections becoming an important crop. Lumbering and clearing for agriculture have increased steadily since then, and their harmful effects began to be felt in certain areas within five to ten years. To-day reckless lumbering and careless and ignorant methods of agriculture are still potent causes of erosion.

PROBLEMS INVOLVED IN THE STUDY.

From the preceding discussion it is evident the subject presents two distinct problems, whose relative magnitude and importance differ in different parts of the region. One of these problems relates to agriculture and the other to forestry.

THE AGRICULTURAL PROBLEM.

The agricultural problem involves the selection of the areas best suited for agriculture because of fertility of soil and moderate slope of surface and the study of the ways in which such areas may best be handled to prevent their destruction through erosion and the destruction of other lands and property by the waste they yield and the floods they help to generate.

Much of the mountain area is properly agricultural land, and as the population increases more and more of this area must be brought under cultivation. This means that steeper and steeper slopes must be cleared, and that danger of erosion must increase unless improved methods of agriculture are introduced. Terracing, contour plowing and ditching, crop rotation, sodding to pasture or meadow, as well as the crops best adapted to the region, especially those most helpful in holding soil on steep slopes, should be studied, and to be of practical value this study must consider all these things as they are directly related to the specific and sometimes peculiar climatic, rainfall, soil, slope, labor, and other natural and economic conditions in the region. It can not profitably be a long-range or general study.

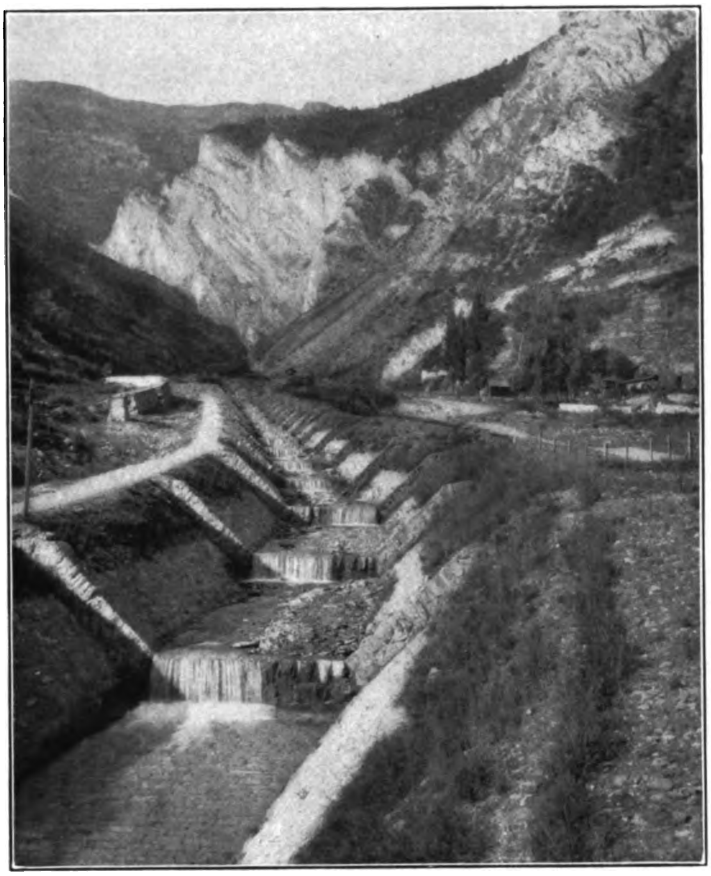
The study of the agricultural problem should also include a consideration of practicable methods of reclaiming eroded and abandoned lands, and of the effectiveness of brush, straw, or other filling for gullies, of brush, log, or rock dams across them, and of tree, vine, or other vegetative covering for bare areas. Such a study should also include a consideration of methods of regulating and restraining both the wild headwaters or torrent reaches, and the lower, but still rapid and easily changeable courses of the mountain streams along whose banks lie the most fertile agricultural lands of the region—lands that are now at the mercy of their uncurbed destructive activities in times of flood.

In studying these problems much could be learned of Europe, where for hundreds of years man has slowly won to agriculture area after area of steeper and steeper slope as population has pressed hard upon subsistence. Doubtless the methods employed in Europe should not be exactly followed, because of differences in climate, crop, soil, labor, and other factors, but, warned by their failures, and profiting by their achievements, we can adapt their successful methods to our own peculiar conditions. Examples of their methods of regulating mountain torrents and preventing erosion on steep slopes are shown in Plate X, opposite. The agricultural lands of the Appalachian Mountains are generally fertile, and if wisely handled will support safely and permanently a much greater population than now inhabits the region.

THE FOREST PROBLEM.

Much of the area is not properly agricultural land, and should not be cleared and forced into agricultural use, because that forcing means quick destruction both of the area itself and of the lower lying areas on the same stream ways. It means also slower, but none the less sure, interference with navigation on the more remote parts of the major stream systems.

The forester would protect steep slopes by keeping them clothed with timber, would coax back tree growth on denuded areas, keep down forest fires, protect and perpetuate the supply



A. A EUROPEAN MOUNTAIN TORRENT THAT HAS BEEN REGULATED.

See page 30.

B. ROCK WALLS BUILT ON A STEEP MOUNTAIN-SIDE FIELD IN EUROPE TO KEEP THE SOIL FROM ERODING.

See page 30.

of hardwood, protect the game and fish, and enhance the beauty and charm of the region as a health and pleasure resort, as well as prevent the navigable streams that flow from these mountains from filling up with the sand and silt, whose removal is now costing annually large sums of money.

DETAILS OF CONDITIONS IN THE REGION.

METHOD OF TREATMENT.

The specific descriptions embodied in the following pages give the data necessary for judgment as to the seriousness of the conditions now existing in various parts of the southern Appalachians and afford some basis, it is hoped, for the intelligent and successful application of remedial measures. The units considered are the major stream basins, which are discussed in the geographical order in which they are found to succeed each other, as one encircles the southern Appalachians by passing southwestward from the Virginia-Tennessee line along the west side of the mountains to central eastern Alabama, there turns eastward around their southern end and then goes northward across Georgia and the Carolinas back to Virginia. The upper portion of the New River basin is then described; and, finally, the Monongahela basin, heading in West Virginia and extending northward to Pittsburg.

The order of description follows the order in which the basins were examined. The position, extend, and relations of the major basins are shown in Plate XI, page 32, and the areas examined in detail in figure 1. The names used for the streams and other geographic and geologic features are those given on the topographic and geologic maps of the United States Geological Survey. These maps, which are listed below, will be found exceedingly helpful in following the discussion.

List of atlas sheets and geologic folios (F) covering the southern Appalachian region and the New and Monongahela River basins.[a]

Abbeville.	Cranberry (F).	Kings Mountain.	Ravenswood.
Abingdon.	Crawfordville.	Kingston (F).	Ringgold (F).
Accident (F).	Cullman.	Knoxville (F).	Roan Mountan (F).
Anniston.	Cumberland Gap.	Lewisburg.	Rome (F).
Asheville (F).	Dadeville.	Littleton.	St. George (W. Va.).
Ashland (Ala.).	Dahlonega.	Loudon (F).	Saluda.
Athalia.	Dalton.	McCormick.	Scottsboro.
Atlanta (Ga.).	Dublin.	Mannington.	Sewanee (F).
Bessemer.	Elberton.	Marietta (Ga.).	Sharon.
Birmingham (F).	Ellijay.	Maynardville (F).	Springville.
Blacksville.	Estillville (F).	Monroe.	Statesville.
Briceville (F).	Fairmont.	Morganton.	Stevenson (F).
Bristol (F).	Fort Payne.	Morgantown.	Sutton.
Brockton.	Frostburg.	Morristown (Tenn.) (F).	Suwanee.
Brookwood.	Gadsden (F).	Mount Guyot.	Talbotton.
Buckhannon (F).	Gaffney.	Mount Mitchell (F).	Talladega.
Burnsville.	Gainesville (Ga.).	Murphy.	Tallapoosa.
Carnesville.	Glenwood.	Nantahala (F).	Vadis.
Cartersville.	Grantsville (F).	Nicholas.	Walhalla.
Centerpoint.	Greeneville (F).	Oceana.	Walton.
Charleston (F).	Hickory.	Opelika.	Wartburg (F).
Charlotte.	Hillsville.	Philippi.	Wedowee.
Chattanooga (F).	Hinton.	Pickens.	Weston.
Clanton.	Huntington (F).	Piedmont (F).	Wetumpka.
Clarksburg.	Huntsville.	Pikeville (F).	Wilkesboro.
Cleveland (Tenn.) (F).	Jasper.	Pisgah (F).	Winfield (W. Va.).
Columbia (S. C.).	Jonesville.	Pocahontas (F).	Wytheville.
Columbus.	Kanawha Falls.	Point Pleasant.	Yadkinville.
Cowee.	Kenna.	Raleigh (F).	

[a] The atlas sheets are sold by the United States Geological Survey for 5 cents each; the folios for 25 cents each.

TENNESSEE RIVER BASIN.

Tennessee River is formed by the union of Holston and French Broad rivers 4½ miles above Knoxville, Tenn. An examination of these streams shows that the Holston is the direct continuation of the Tennessee up the great Appalachian Valley, and for this reason the head of the Holston is here treated as the head of the Tennessee.[a] The main tributary basins from the eastern or Appalachian Mountain side will first be described in order from the Holston southward to the Hiwassee, and the description of these will be followed by a description of the Tennessee itself from Knoxville, Tenn., to Paducah, Ky. No examination was made of the streams entering from the west or Cumberland Mountain side of the basin.

HOLSTON BASIN.

GENERAL FEATURES.

The basin of Holston River has an extreme length of about 170 miles, of which the lower 141½ miles, below the junction of the north and south forks near Kingsport, Tenn., is narrow and receives but little drainage. Above this junction the basin has an average width of perhaps 50 miles. The slope of the north fork of the Holston is about 6 feet per mile; that of the lower 141½ miles is 2.55 feet per mile. This slope is, however, by no means uniformly distributed, but quiet pools and shallow reaches succeed each other at varying intervals throughout the course.

All of the larger streams of the Holston basin flow either on rock bottom or over bed rock that is covered at ordinary stages by a foot or two of loose sand and gravel. During floods this loose material is undoubtedly set in motion and the bottom is subjected to powerful scouring action. The streams are thus actively degrading or deepening their channels, and the material consequently has no general tendency to lodge and accumulate in great quantities, so that bars and islands as a rule are not growing. During floods, however, more material is furnished than can be removed and the excess is deposited to build flood plains, which waste as erosion progresses; and as the channels are deepened new flood plains at lower levels are formed and the older ones are left as fossil flood plains, many of which may be observed at different levels along the sides of the valleys.

Flood crests on the Holston, as well as on other streams of equally high gradient, as a rule have steep fronts, advance rapidly, and recede with almost equal rapidity. As might be expected, such floods are usually destructive.

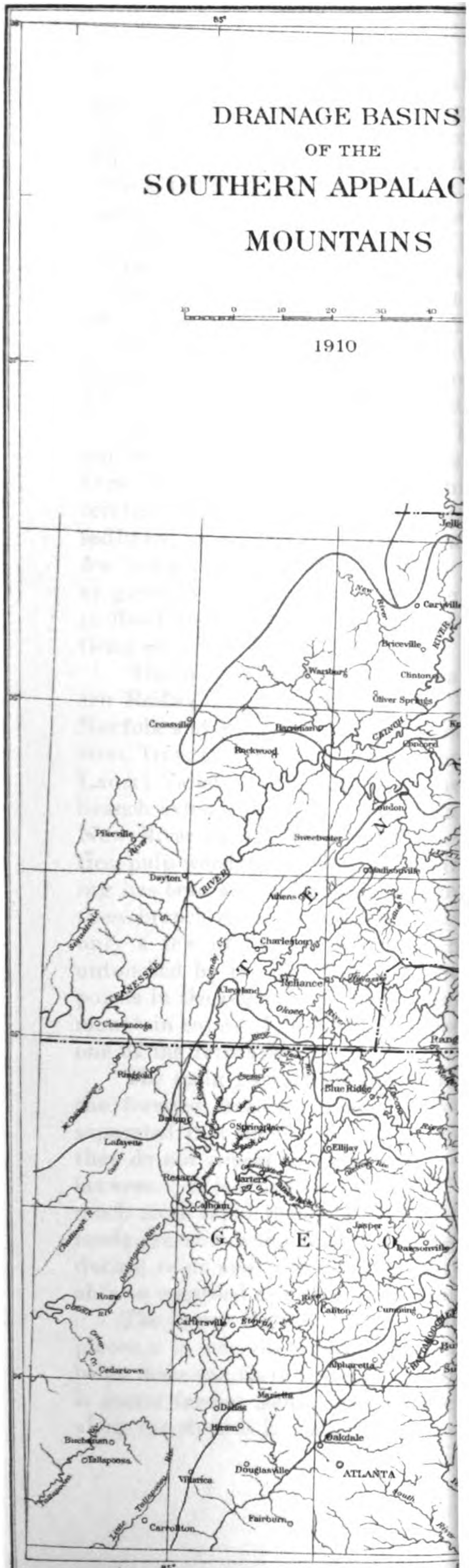
HOLSTON BASIN ABOVE THE MOUTH OF WATAUGA RIVER.

No detailed examination was made of the extreme upper part of the Holston basin, but in the course of several trips across it the general conditions were noted.

The upper Holston basin is drained by the North and South forks of the Holston, which flow southwestward in harmony with the general trend of the mountain ridges of the region and which, with their tributaries, show a marked parallelism in their courses. This parallel arrangement is due to the folding, faulting, and subsequent erosion of the rocks of the region, whose upturned and eroded edges trend northeast and southwest. These Paleozoic rocks offer unequal resistance to erosion; some weather rapidly and others very slowly, so that areas of soft shales and limestones have been carved into valleys and beds of resistant chert and sandstone or quartzite stand up as ridges. The country is therefore characterized by long, narrow valleys, separated by equally long, narrow ridges, with steep slopes and in many places sharp crests.

The valleys are usually fertile and level or gently rolling, and are largely cleared. The soil, which is commonly formed of limestone or calcareous shale, the elevation, which ranges

[a] In the stream-measurement reports of the United States Geological Survey the French Broad, because of its greater drainage area, is treated as the upper extension of the Tennessee.


DRAINAGE BASINS
OF THE
SOUTHERN APPALAC
MOUNTAINS
1910
Caryville
Briceville
Clinton
Wartburg
Oliver Springs
Crossville
Harriman
Rockwood
Loudon
Pikeville
Sweetwater
Madisonville
Dayton
Athens
Charleston
Cleveland
Reliance
Chattanooga
Ringgold
Blue Ridge
Dalton
Ellijay
Lafayette
Resaca
Calhoun
Jasper
Dawsonville
Rome
Cartersville
Canton
Cumming
Alpharetta
Cedartown
Marietta
Dallas
Hiram
Buchanan
Tallapoosa
Oakdale
Douglasville
Villarica
ATLANTA
Fairburn
Carrollton
G E O
T E N

from 1,400 to 2,500 feet, and the rainfall, which averages about 45 inches a year, make this a natural grass region, and a very large proportion of the cleared area is in meadow or pasture land, though some corn and small grains are raised. Many of the richer slopes also are cleared for several hundred feet up their sides, and the tops of many of the ridges are also in grass. Where the land is sodded there is practically no erosion. Each year more and more of the cultivated land is being put in grass.

Most of the Holston valley in Virginia lies in Washington and Smythe counties. About 77 per cent of the area of these counties is classed as farm lands by the Twelfth Census, and of this farm area about 57 per cent is cleared. The 23 per cent not in farms consists largely of timber areas in the rougher or more mountainous portions of the counties. Much of the timber has been or is being cut, and practically all of it is in the hands of lumber companies. From 45 to 50 per cent of the area of these two counties and probably 50 per cent of the entire Holston basin in Virginia is cleared, and much more than half of the cleared area is in grass.

That the erosion of this cleared land is in most places very slight is evident, but close examination of some of the slopes reveals the presence of isolated gullies or bare, eroded areas, and here and there a slope of shale, which weathers to a fine-grained, compact clay, also shows a tendency to gully. In flood the streams in the region do not carry so large an amount of sediment as is borne by streams draining areas where a larger part of the slopes are bare, as, for instance, those farther south in the Appalachians. The flood waters are usually brownish or grayish in color and not the deep yellow or red shown by the more southern streams when in flood, the discoloration being due more to decaying vegetable matter than to suspended particles of soil.

The upper Holston valley is traversed lengthwise by the Norfolk and Western and Southern Railways and crosswise by the Virginia and Southwestern and by several branches of the Norfolk and Western, one branch extending southeastward from Abingdon, Va., into the Holston, Iron, and Stone mountains, one going down Shady Valley, and another up White Top Laurel Valley, making available the timber within the southeast edge of the basin. Another branch extends southward from Marion, Va., across the Iron Mountains into the edge of the New River basin. These roads furnish transportation for large quantities of lumber, crossties, pulp wood, tan bark, and tanning-extract wood. Along the main lines of railway lumbering has been active for years and most of the good timber has been cut. The construction of these branch roads has made it possible to extend the operations back into the mountains, and only a few of the more remote and inaccessible coves of the upper Holston basin remain untouched by the ax. Large lumber plants are established at Bristol, Abingdon, and other points in the region, and many small mills are located on the branch railways or back in the mountain coves. Lumber from these small mills is hauled by wagon 20 miles or more to reach one of the railways.

The main part of the upper Holston valley needs no protection from erosion. Most of the forested areas lie along narrow ridges, each of comparatively small extent, that are so separated that they could not be segregated from the cleared lands of the basin. Moreover, they do not appear to be in special danger nor are they apt to become a menace to the valleys between. It is true that the run-off from the sodded slopes and valleys during heavy rains is much more rapid than that from a wooded area with abundant humus, yet undoubtedly these lands are now being put to the best possible use, and though they give an increased run-off during rains and perhaps a slightly greater flood-crest height, such conditions should probably be regarded as unavoidable consequences of man's use of the region.

The upper Holston valley is not subject to extraordinary damage from floods. In some places, it is true, the streams are cutting; in others they are building; but no serious damage is being done and there is not the great volume of detritus working into the stream channels that is found farther south, where the cleared areas are not sodded. The amount of destruction along the streams is consequently much less than along the streams farther south.

Along its southeastern edge the upper Holston basin is separated from the New and Watauga basins by a rough, mountainous country, which is crossed by the Holston, Iron, and Stone Mountain ranges, and a large portion of which is so steep, rough, and stony that it can never be used for farming. In this region lumbering is active.

WATAUGA RIVER BASIN.

Watauga River rises in the Blue Ridge near the head of New River and flows northwestward to its junction with the south fork of the Holston. Its basin is compact in shape and may be divided into two parts—a larger eastern part, lying within the mountains proper, and a smaller western one, which lies in the great valley of east Tennessee. The conditions in the mountainous portion are of chief interest for the purposes of this report, but the conditions along the lower part of the stream will also be described.

UPPER WATAUGA BASIN.

The upper part of the Watauga basin has an elevation along the stream itself of 1,700 to to 3,000 feet above sea level, but a large part of its surface is much higher and within or around its margin there are many peaks 5,000 feet or more in altitude. Grandfather Mountain is 5,964 feet high, Hanging Rock is 5,237 feet, and Roan Mountain is 6,313 feet. The surface is much broken by long-continued erosion. The tributary stream valleys are narrow and deep and are separated by steep and usually densely wooded ridges. The streams have steep gradients and high velocity, and consequently great destructive power during floods. The damage from floods in this basin in 1901 amounted to $2,000,000.

The examination of the Watauga basin began at Johnson City, Tenn. At Watauga Valley, where the river itself was first reached, evidences of the great flood of 1901 were seen on all sides. The bottom lands had been badly washed and torn to pieces. In some places the roads had been entirely destroyed by the erosion of great holes; in others white sand had been spread deeply over lands that had previously been highly fertile. At one place the railway company now has a sand pit where large crops of corn were formerly raised. Much of this Watauga bottom land can not be remade in years. Estimates of the average amount of damage place it at about 75 per cent of the original value of the land. Considerable areas of land, formerly worth from $75 to $100 an acre, were unsalable after the flood. The greatest destruction occurred near the river. In many places 6 or 8 feet of soil has been stripped from a belt 100 to 150 yards wide, exposing the underlying stream bowlders or the edges of upturned limestone beds.

At Elizabethton the river broke from its channel and swept through the town, destroying one street entirely and cutting a new channel, which the town has attempted to close by building a stone and crib work dam across its upper end. It will be years, however, before the channel thus excavated in a few hours can be filled up and obliterated.

Doe River above Elizabethton shows similar flood effects, much of the bordering land having been destroyed by the same process of soil stripping or sand covering.

The Watauga and the Doe are in most places bordered by a narrow ordinary flood plain, above which is an extraordinary flood plain 100 to 1,000 yards in width. The narrow, ordinary plain is frequently covered by floods, so that crops growing on it are liable to destruction at almost any time. Formerly the higher, extraordinary plain was rarely seriously injured by high waters, but in recent years high water has reached it more frequently and covered it more deeply, and very much of the destruction in 1901, both of bottom lands and of crops, roads, and railways, was on this extraordinary flood plain. It can no longer be regarded as reasonably safe from floods, and its value has been greatly lessened, both because of this fact and because of the actual destruction already wrought on the land itself.

Older fossil flood plains may be seen along both rivers at various heights. One that is particularly well preserved is 80 feet higher than the extraordinary plain now being damaged by floods. It contains in places an abundance of rounded bowlders up to 1 or 2 feet in diameter that once formed its base, just as many present-day flood plains of fine alluvial material are

underlain by a bowlder bed at their base. About 50 feet higher there is another still older fossil flood plain or terrace, whose surface is also characterized by rounded bowlders, but is much dissected by erosion and is preserved to-day only in remnants. These old flood plains, formed when the river flowed at a distinctly higher level than now, are, of course, above the reach of even the most extraordinary floods, but long leaching and the cessation of alluvial deposition have left the soil little of its original fertility.

Five miles above Elizabethton Doe River passes through a narrow, precipitous, rocky gorge. The railway through this gorge was practically destroyed, and above the gorge practically all bridges as well as much of the track of the remainder of the line up to Cranberry, N. C., were swept away and destroyed in 1901.

Allentown suffered much from the same flood. County bridges were destroyed and many houses were swept from their foundations or wrecked. A large part of the destruction here, as elsewhere, was caused by sawmill refuse—slabs and other floating timbers—which, in the grasp of the swift waters, acted as battering rams or lodged and formed rafts that grew until they ultimately swept everything before them.

From Allentown northeastward to Watauga River a considerable area of steep slopes has been cleared, but the soil is somewhat porous and sandy and much of the rainfall is absorbed, so that there is comparatively little erosion. Along the Watauga, above its gorge through the Iron Mountain, evidences of flood damages are numerous; bottom lands were washed away, roads were torn to pieces, and railroad bridges and embankments were generally destroyed.

The bottoms up to Butler are cleared, although the steep slopes on either side are usually wooded. At Butler a steel highway bridge was swept away, much land along the river was injured, and cleared areas on the hillsides were badly washed. Above Butler the Watauga Valley contains practically no bottom lands. In this part of its course the river cuts through Stone Mountains in a narrow, steep-sided gorge that is not cleared, and only small patches of flood plain are found until the valley widens near Valle Crucis, N. C.

The lands about and above Valle Crucis, past Shulls Mill and on to the head of the river, have in recent years been much injured by floods. The channel of the stream has been filled with débris to such an extent that the river overflows its banks easily, and its descent is so rapid that many parts of the adjacent bottom lands have been much washed and gouged, or once fertile fields have been thickly overspread with cobbles and gravels. Along the steep valley slopes are considerable areas of cleared land which in places show much gullying.

Practically all of the upper part of the Watauga Valley is an area of granite. Where the granite is coarsely crystalline in texture it weathers into a soil that is porous enough to absorb much of the rainfall and prevent extensive erosion; where it is finely crystalline it weathers into a more compact clayey soil that is not nearly so pervious, and erosion is much more pronounced. Steeply sloping areas underlain by the fine-textured type of this granite should, if possible, be kept in timber; those underlain by the coarse-grained type can be cleared with much less risk of destruction by erosion.

Another effect of the rapid erosion and filling of the channel of the Watauga appears in the bars and islands, which may be seen at many places above and below Valle Crucis. Sand and gravel lodging in shallow places becomes covered with various plant growths, and in a few years forms an island which deflects the stream current and causes erosion of the banks. At other places where the steep tributary basins have been cleared, the Watauga is unable to remove all the débris brought to it by the streams, and broad fans or cones of sand and gravel are forming at the mouths of these tributaries and are tending to push the Watauga to the opposite side of the valley. The obstruction of the main channel that originates in this way may in time increase to such an extent as to pond the Watauga and convert the bottoms immediately above into marshes or lakes. Dutch Creek has formed an especially well-marked alluvial fan of this type, which has already ruined a number of acres of fine bottom land. The owners of the land along this upper part of the Watauga have tried in various ways to prevent its destruction by the river and its tributaries. In some places they have built stone cribbing or brush training walls; in others they have faced the cribbing with sheet piling.

Above Shulls Mill every mill and dam was washed away by the flood of 1901 and bottoms were damaged from 15 to 25 per cent of the former value of the land. Mills, dams, and bridges on several of the tributaries of the upper Watauga were also carried out, and some of the steep cleared hillsides were damaged more than 25 per cent. A considerable part of the damage to cleared hillsides is alleged to have been due to the snaking trails, made by the lumbermen on the higher wooded slopes, which furnished runways for the water and concentrated it on the lower cleared slopes. The county has, at no little cost, replaced the bridges, and in places has relocated and graded roads along the hillsides above the reach of future floods.

Above Foscoe the higher slopes on the south side of Hanging Rock Mountain have been largely cleared and many of them have washed badly, especially within recent years, so that they now present many bare red-clay areas. On the north and west slope of Grandfather Mountain very little clearing has been done. The cleared land is practically all in grass and has not washed to any appreciable extent. The Moody Mill Creek and Boone Fork regions are not largely cleared, and erosion does not seem to be especially active in either of these basins.

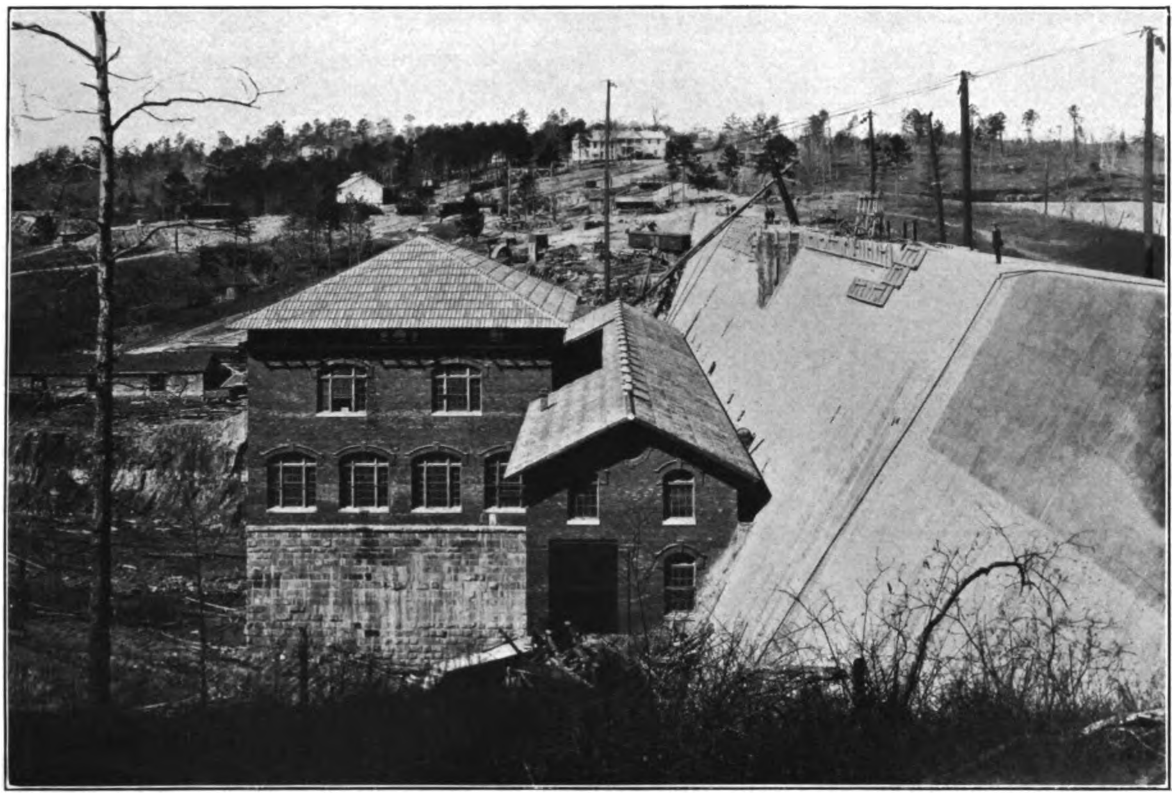
At the head of Banners Elk Creek there is a good example of erosion of a lower wooded slope caused by water concentrated by ditches from fields on the higher slopes above. Two miles above Banners Elk cleared bottom lands are seen; the stream is very swift, however, and in floods cuts new channels at many places and leaves the flood plain surface in a hummocky condition. It is, in fact, rather a cobble torrent plain than an alluvial plain and can be made safe from erosion only by building extensive retaining walls or other devices for holding the stream in check. The land is not especially fertile and some parts are poorly drained and swampy.

Much the larger part of the area between Beech Mountain and Hanging Rock is wooded and wild. Most of the cleared areas noted were on the slope of Beech Mountain and were not eroding badly, perhaps because the rocks of the Beech Mountain area consist of a coarse porphyritic granite, which weathers into a loose, porous soil that permits the rapid downward percolation of the rainfall and thus greatly decreases the run-off. From Banners Elk to Elk Park the stream flows in a steep-sided more or less rocky gorge, its descent is rapid, and erosion has been so active that, except in a few areas of soft rock, it has built little or no flood plain. Where flood plains have been made they are rather beveled, sloping plains than true flood plains, the edge near the stream being much lower than the part near the valley wall. Such plains result where the stream slowly shifts laterally while cutting down vertically, forming on one side a beveled slope of which only the lower edge is ever covered by floods and which embraces in successively higher portions the ordinary, extraordinary, and fossil flood plains; on the other side there is usually a steep slope or an undercut bluff. Here and there where the gorge is not exceedingly steep the fields have been cleared and in places these show the effects of erosion.

Forty to 60 per cent of the area from Elk Park northward across Beech Mountain to the valley of Loggy Gap is cleared and some of it is rather steep, but it shows little erosion, for its soil is made up of decomposed granite of coarse texture and is usually porous enough to absorb a large portion of the rainfall. Near Loggy Gap, however, the rocks weather into a closer-grained soil that is more liable to erosion on steep slopes.

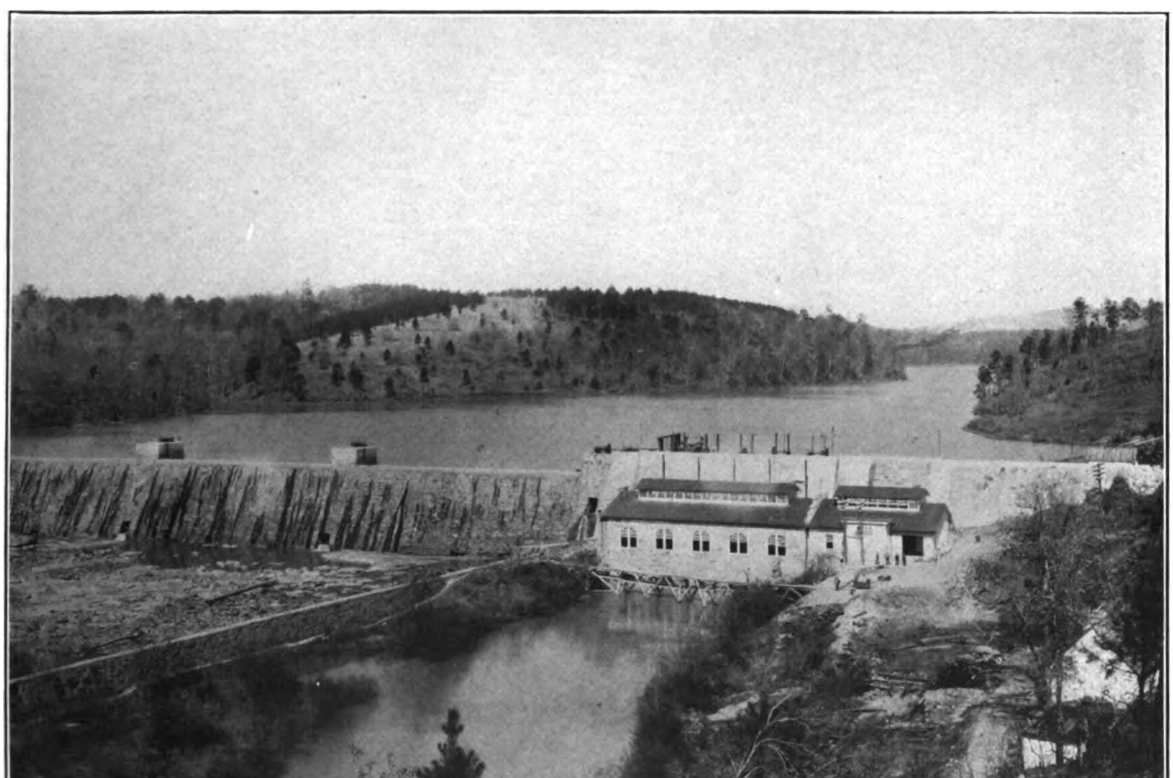
The mountain sides from Loggy Gap to the mouth of Beech Creek are 30 to 40 per cent cleared; from Beech Creek down to Norris only the higher slopes are cleared, the lower portion of the slope forming an almost precipitous gorge. About Norris there are some small areas of rock which weather to a compact clay, and where cleared these areas show extensive gullying.

Elk Creek, one of the important southern tributaries of the Watauga, flows in its lower course in a narrow valley cut in shales. At ordinary stages the stream is actively degrading its channel and flows almost everywhere on the upturned edges of the shales; during floods, however, it can not remove all the débris brought to it, and at a number of places where the shales are rather soft it has built a flood plain 100 to 300 yards in width. This flood plain is usually about 10 feet above ordinary water level, and is underlain near water level by a cobble



A. POWER HOUSE AND BULKHEAD AT GREAT FALLS STATION OF THE SOUTHERN POWER COMPANY, ON CATAWBA RIVER, CHESTER COUNTY, S. C.

See page 14.



B. PORTMAN PLANT OF ANDERSON (S. C.) WATER, LIGHT, AND POWER COMPANY, ON SENECA RIVER.

See page 14.

and bowlder bed, such as is left in this region by most streams having considerable slope and rapid current. At Elk Mills the flood plain is about 300 yards wide, but the stream is so active and restless that during floods it is constantly undercutting its banks on one side or the other and shifting its position. In this way it has stripped a zone 100 to 150 yards wide and converted it into a cobble and bowlder belt. This shifting is not, properly speaking, meandering, for the stream is too vigorous to develop conventional meanders. The shifting is irregular and spasmodic, occurs during floods, and seems to be due to choking by chance obstructions or to abrupt bends in the channel, which during floods strongly deflect the current against one bank or the other. The swift current rapidly sweeps away the alluvial soil and forms a new channel.

The amount of waste carried by this stream has increased notably during recent years. A dam at Elk Mills that was originally only 3 feet high has been so filled with débris that the owners have been compelled to raise it 2 feet in order to regain its storage capacity. It is evident, however, that this expedient will afford but temporary relief, for the dam will soon be full again and the owners must lose the value of the dam and either utilize merely the flow of the stream or abandon the mill.

The source of this waste is easily recognized. The hills on the sides of the stream are unusually steep and have been so deeply cut by erosion that they have a rounded, knob-like appearance. They are very largely cultivated, and the fine, close-grained soils resulting from the weathering of the shales permit but little percolation and have gullied badly. Crude efforts have been made to check erosion by building loose rock dams at intervals across the gullies, but these dams are rapidly filled with fine clay and have not greatly checked, much less remedied, the evil. The hills are planted largely in grain, only a small area being kept in grass, and these lands must therefore soon lose their soil and be abandoned unless they are terraced and sodded.

Some 3 miles above Elk Mills granite succeeds the shale, the flood plain disappears, and the valley walls remain uncleared, though of but moderate slope. In this region lumbering was actively in progress when the stream was visited, and a logging chute was being made from the eastern valley side down to the Elk. This chute will ultimately be converted into an erosion channel, as have other older logging chutes higher up the stream. At the foot of these older chutes notable fan-like or cone-like accumulations of rock and gravel have already formed.

Near the State line there are some clearings and small flood plains. One at least of these plains has been formed by the complete filling of the impounding area above a milldam. In some places the flood plains have been covered by barren white sand during floods, and in these localities they are now of little or no agricultural value. In other places they have been badly eroded during floods and are now abandoned. At no place in this upper portion of the stream is the flood plain more than a very few feet above ordinary water level, so that overflows are frequent, crops are extremely uncertain, and conditions are tending to become constantly worse. Under present conditions these lands may be regarded as of practically no value.

Roane Creek enters the Watauga from the north a short distance below the mouth of Elk Creek. From its mouth at Butler, Tenn., for several miles upstream its living flood plain is relatively broad and stands at an average height of about 8 feet above water level. In places this flood plain is badly washed and at a point 2 miles northeast of Butler a railway bridge and several acres of fertile lands have recently been swept away and some bad runs or diversion channels have been developed across the once fertile bottoms. Such runs are especially likely to form across meander curves, as may be seen in Plate XIII (p. 38). About 35 feet above this living flood plain there is a well-defined high or fossil flood plain, which is safe from any possible overflow. This stream channel, like that of Elk Creek, is shifting, and although it is not generally degrading its bed, it has developed a bowlder zone that is in places more than 100 yards wide. The hillsides are steep and most of them are cleared and cultivated for a vertical distance of 100 to 300 feet above the valley. The soil on these slopes is porous and does not wash badly.

Doe Creek enters Roane Creek at Mouth of Doe in a narrow gorge. Across this gorge has been built a milldam, the pond above which in recent years has filled completely with sand and stones. In its stretch above the dam the stream is unable to remove the débris furnished to it by its tributaries and is distributing silt along its way, aggrading its flood plain and menacing its bottoms. The steep hillsides show many washes, which end on the edge of the flood plain in stony alluvial fans or cones. The aggradation in the main stream has given it a tendency to meander, and just below Doeville a long rock-filled crib has recently been built to protect the bottoms. The steep shale slopes west and northwest of Doeville are cultivated and are washing and gullying. Above Doeville the numerous tributaries of Doe Creek from the west have built long, low sandy or stony fans where they strike the Doe Creek flood plain and have in the aggregate destroyed a considerable area of good bottom lands. In some places the steep slopes erode into gullies; in other places several small, shallow gullies have coalesced into one broad erosion plain from which the soil has been entirely stripped.

At Pandora the valley narrows and steep shale hills rise abruptly on its sides. These slopes are cleared in large part and in many places show the characteristic results of shale erosion. Several miles farther upstream the valley widens again and about Little Doe a broad, sloping, or beveled flood plain has been developed. The valley walls are not so steep here and the erosion of the cleared slopes, though under way, is not so vigorous nor so destructive as along the lower course of the stream.

At Mountain City the slopes in general are moderate, and, though largely cleared, do not suffer badly from erosion.

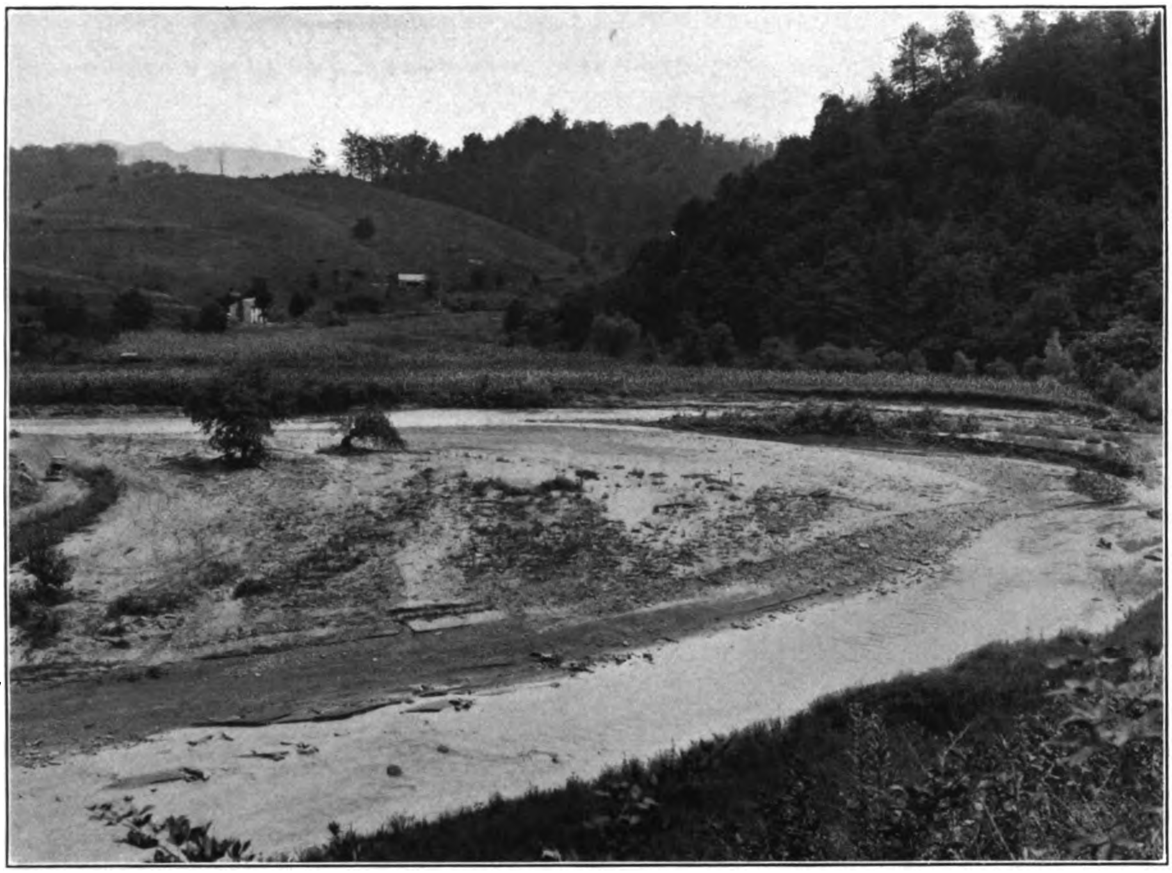
At Rhea Forge, and for a number of miles down Roane Creek, there is a relatively broad, well-developed flood plain, which has been affected in many places by recent floods. The railway along the flood plain has also been seriously damaged. Forge Creek, one of the tributaries of Roane Creek, has done much damage. Many of its valley slopes are badly washed, and the ponded area above the dam that once furnished power for an iron forge and furnace has been completely filled with sediment and is now converted into a cornfield.

Along Roane Creek, above Rhea Forge, there is very little bottom land. The hillsides are exceedingly steep and in many places are cleared, especially on the east side of the creek, and are washing to a considerable extent. Still farther upstream the forest-clad gorge is wild, rocky, and narrow. Just below Key Station the valley widens again and the slopes become gentler. These slopes have been cleared and are mostly in small grain or corn. Much of the clearing has been done recently, and the soil still retains a portion of its humus and has not yet begun to erode badly. The granite rocks of this region weather into a porous soil, which tends to minimize surface erosion.

About Trade and on to the State line 70 to 80 per cent of the steep mountain slopes have been cleared. Perhaps over half of this cleared area is in grass and is not being injured by erosion; the remainder is kept in corn and small grain and would rapidly wash away were it not for the porousness of the soil. Notwithstanding this, however, considerable areas have been badly gullied, and the only safe course for the farmer to pursue in order to prevent erosion is to keep the lands in grass.

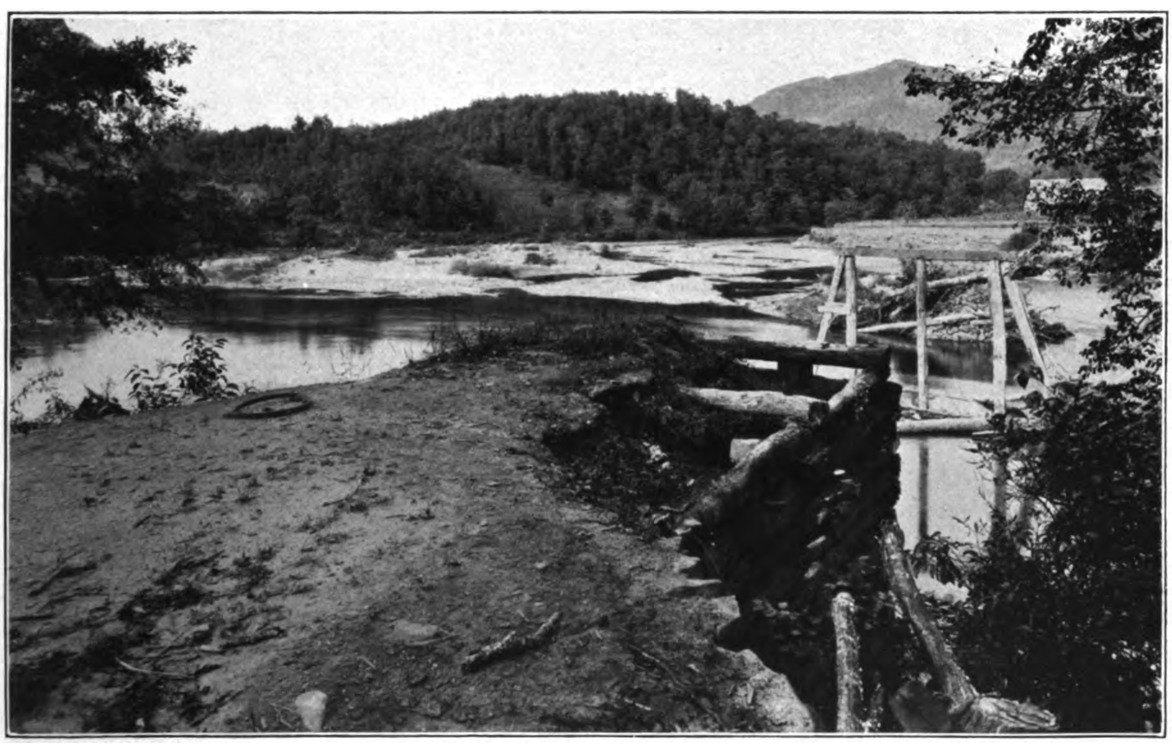
At Zionsville many of the steep hillsides are cleared to the very tops. Cove Creek is a steep torrential stream that is frequently shifting its channel, so that its narrow flood plain is composed of coarse material and is repeatedly being cut to pieces and refashioned. Along the stream there are indications that aggradation is going on rapidly. A few miles below Zionsville the stream gradient is not so steep and the position of the channel is consequently more stable. The alluvial flood plain in this lower part of the creek is composed of finer material and is more valuable for agriculture. It has not yet been seriously injured by floods.

Farther down Cove Creek valley there are numerous mountain-side clearings, and although the rocks of the region are granitic many of the cleared slopes are so steep that erosion is active. At a point a mile north of Mast, for instance, many steep mountain-side fields have been abandoned to gullies, briers, and broom sedge; others, though badly washed, are still cultivated. From these cultivated areas most of the fertile soil has already been removed, and the crops



A. EROSION ON INSIDE OF MEANDER CURVE.

See page 37.



B. CULLASAGEE RIVER CUTTING A NEW CHANNEL (TO THE RIGHT) ACROSS A MEANDER CURVE.

See page 37.

now grown scarcely warrant the little work bestowed upon them. In general, little or no effort is being made to prevent the erosion of these steep fields, and it will not be many years before they, too, must be abandoned. Milldams along this valley, even those built only a few years ago, are nearly full of sand and gravel.

These granitic soils erode into long, narrow, parallel gullies that run straight down the steep slopes. They gradually deepen and widen until the entire original surface has been removed and the edges of adjacent gullies coalesce, leaving the once fertile fields a maze of erosion-formed ridges and grooves, whose cross section has a serrate profile. From some cleared areas on these granitic slopes, as, for example, near Sugar Grove, portions of the surface have slipped off and left bare spots. Erosion by such landslides is more likely to occur where the granite is micaceous or is of a gneissoid type, or has suffered spheroidal weathering and is fractured in planes of easy parting that may be inclined at angles favorable for the production of landslides. Such slides occur usually in wet weather, especially late in the winter or early in the spring, and may be started by the trampling of cattle.

The flood plain of the lower valley of Cove Creek is 100 to 300 yards wide, and the position of the stream channel is mainly stable, although here and there it shows a tendency to shift and has produced a narrow zone of cobble. The stream is also aggrading somewhat. The mountain-sides are cultivated up to a vertical distance of 300 or 400 feet above the valley. Cove Valley is bounded on the east by Beech Mountain Range, which rises to a height of 5,369 feet. The upper slopes of this range are densely wooded, but some clearings occur on its lower slopes. These, as well as clearings on other high mountains in the vicinity, are kept in grass and grazed, so that erosion here is not active.

The cleared lands on the steep slopes on the sides of some tributaries of Cove Creek have been kept largely in grass, and the condition of the narrow flood plain along these streams, as well as that of the steep slopes themselves, is very much better than where clean culture has prevailed.

The inhabitants of the Cove Creek region generally realize that erosion is becoming worse and that damages from floods are becoming greater. They say that destructive floods are more frequent than in former years and attribute these changes to the operations of lumbermen and the clearing of steep lands, but they are taking practically no measures to remedy the evils. The steep fields are cultivated as long as possible and are then abandoned.

Lumbering is active in most of the Watauga basin, and long trains of wagons carry lumber to the railways at Mountain City, Butler, Cranberry, Elk Park, and other places. In some localities destructive forest fires have followed in the wake of the lumberman; in others the forest is reproducing itself where the area lumbered has not subsequently been cleared and placed in cultivation or grass.

For about 3 miles from the head of Wilson Creek the stream flows with a rapid current in a narrow valley devoid of flood plain. The mountain sides are steep and generally wooded, so that the valley may be said to remain in a state of nature and to be occupied merely by the stream and railway. Farther down the creek the valley widens gradually and the stream has formed a flood plain. At the mouth of Shell Creek this flood plain is some 200 yards wide, but about half of it has recently been ruined by floods and abandoned. From this point down to Roan Mountain station from one-half to three-fourths of the flood plain has been similarly destroyed. The principal belt of destruction is a cobble zone on either side of the stream, where the soil has been entirely stripped from the flood plain. This zone of destruction is more nearly straight than the stream channel itself, which winds irregularly back and forth across it and is constantly shifting its position. As a rule the belt of destroyed flood plain is wider just below the mouths of tributary streams, undoubtedly because of the cross currents set up during floods by the entrance of such tributaries.

Along its entire course, from above Shell Creek downward, Wilson Creek is overloaded with débris and is depositing on its flood plain the material it is unable to remove. The flood plain is consequently building up or aggrading, and distributaries are given off by the main channel at short intervals. These streamlets cut narrow channels, which are only 2 or 3 feet

below the surface of the flood plain, and after short courses many of them end in fans of sand and cobbles that they have spread over the once fertile surface.

The valley walls are retreating, and at many places poorly preserved remnants of an old stream terrace stand between 100 and 150 feet above the present surface of the flood plain. The valley sides are largely cleared and cultivated. If after clearing they are kept for a year or two only in grain and then sodded the surface is protected from erosion reasonably well, but if they are cultivated for several years until the original humus has been lost it becomes difficult to establish a sod, and erosion almost invariably occurs. Several such eroded areas may be found, especially on the south side of the valley. The surface generally cuts into deep, narrow gullies that run radially down the rounded hills. In a few places sheet wash was observed.

At Roan Mountain the flood plain is 300 to 400 yards wide and the tributary entering from the south has built an alluvial fan of sand, cobbles, tree trunks, and other débris that extends entirely across the main flood plain and has pushed the larger stream against the opposite valley wall. A mill here develops 40 horsepower, but the owners report that during the last twenty years the character of the stream has materially changed, its flow having become less constant, so that during the low-water season in September and October they are now able to develop only about 20 horsepower, and are then forced to cease operating a part of their machinery.

Below Roan Mountain the valley narrows and the little flood plain that was once there has been largely destroyed by floods in recent years. A few years ago the railroad was almost entirely washed away and had to be practically rebuilt. All of the small mills and dams on the stream were torn away and many of them have never been replaced.

The stream was formerly almost always clear and was stocked with fish. Now it is usually clouded with silt; the pools that were once the home of the fish have been filled with sand and mud and the fish have disappeared. The people of the region attribute this change to the greater erosion caused by the lumbering and the increased clearing of steep slopes that have resulted from the building of the railway up the valley, and they realize that conditions are becoming worse yearly. In places the cutting of timber on high slopes and the dragging of it down have caused serious damage to the lower slopes. No special effort is being made to guard against erosion, either along the valley or on the slopes.

For some distance south of Roan Mountain station, on the road to Cloudland, the flood plain is relatively narrow, the stream is rapid, and the bottom lands have been largely washed away. Three miles south of the station the valley widens somewhat, but about half of the flood plain has been rendered useless by recent floods. Above this the flood plain again narrows, becomes more stony and hummocky, and is constantly shifting and reforming under the influence of the torrential stream. Above Burbank the flood or torrent plain is so stony and rough as to be practically worthless. Below Burbank 40 per cent of the hillsides have been cleared. From Burbank upstream practically all the hillsides are in forest, though the best timber has been removed.

Well up on the north side of Roan Mountain there are a few small clearings, above which the mountain is densely wooded almost to the top, where it becomes an open, naturally treeless sodded slope—a "bald." Most of these balds are well grazed, but the trampling of cattle has broken the turf on the bald of the Roan and started gully erosion in many places. The porous, disintegrated granitic or gneissose soil, 2 to 6 feet deep, is quickly removed down to the solid rock. The gully then widens until it has become a channel 10 to 15 feet wide. No effort is being made to check this erosion. From Cloudland the spurs of the Roan to the north are heavily wooded and show no clearings. To the northwest, near the head of Big Rock Creek, some of the steep slopes have been cleared. About half of the cleared area is in grass and the other half shows some erosion. At the head of Little Rock Creek there are many mountainside clearings, which show little erosion, undoubtedly because they are underlain by a granite whose disintegration produces a porous soil.

LOWER WATAUGA BASIN.

The valley of the Watauga below Johnson City, Tenn., is relatively narrow for about 8 miles. In this stretch the Southern Railway bridge and a $7,000 county bridge has recently been swept away. At De Vaults Ford the valley again widens and for a few miles the stream is bordered by excellent bottom lands, which were damaged about 20 per cent in 1901, when half of De Vaults Island was destroyed. From the ford down to the mouth of the Watauga the bottoms are in relatively narrow strips, many of which were utterly destroyed, and just at the mouth of the Watauga the piers for a railway bridge were wrecked. These bottom lands were previously worth $75 to $100 an acre, and the average damage on the entire lower portion of the river was 20 to 25 per cent.

The lands at De Vaults Ford had not been covered with water since the first settlement of the country in 1768 until the floods of 1860 and 1867, which ran through them but did practically no damage. The flood of May 21, 1901, and that of February, 1902, which was almost as high, completely covered and seriously injured these lands. This land of De Vault's lies on an extraordinary flood plain—that is, one so high that only floods of exceptional height ever reach it—hence it is rarely subject to flood damage. It is bordered on the stream side by a narrow ordinary flood plain that stands 8 to 10 feet lower and on the other side by an older terrace, 40 to 50 feet higher, which is covered with stream cobbles and separated from it by a sharp scarp. About 75 feet above this older terrace is a spur with stream bowlders that mark another old flood plain. A third old or fossil stream plain, with rounded bowlders up to 1½ feet in diameter, lies 60 feet higher still, at an elevation of 1,555 feet above sea level.

The flood in the lower valleys of small tributaries of the Watauga was ponded at places where they enter the main stream, and at these places rich soil was deposited which greatly benefited the lands.

HOLSTON BELOW THE MOUTH OF WATAUGA RIVER.

Much damage was done on the south fork of the Holston from the mouth of the Watauga down to Kingsport. Where the north fork enters, 25 per cent of Long Island was destroyed, and though a farm here and there was improved by being covered with rich silt deposits borne by the eddying waters, the assessment for taxation of the bottom lands of Sullivan County was lowered 20 per cent on the average because of damage done by the floods of 1901 and 1902, and the assessment on some farms was reduced 75 per cent. Besides the damage to the lands, considerable additional damages resulted from the sweeping away of fences and young growing crops. The damage to buildings was slight for few of them stand within the reach of floods.

Near Kingsport the ordinary flood plain, or first bottoms, as it is called, is about 12 feet above ordinary water stages. About 8 feet higher there is another flood plain—the extraordinary one. Both of these were covered by water and greatly damaged. About 65 feet higher there is a third high-stream terrace or fossil flood plain, and 75 feet still higher there is a fourth, at an elevation of 1,300 feet above sea level. This last is broad and flat and is well strewn with stream cobbles.

Down the Holston the ordinary and extraordinary flood planes are typically developed and together average probably 200 yards in width. These lands are worth $50 to $60 an acre. About two-thirds of the farmers in this region report recent flood damages ranging from 20 per cent to 50 per cent of the land's value, while the remaining one-third were benefited by rich silt deposits from eddy water. The average damage for the entire area would amount to perhaps 25 per cent. A number of islands were badly damaged, the upper, more exposed ends having been washed off and the lower ends covered with sand. Some new islands were formed where the stream cut across bends.

At Stony Point the bottoms are a half mile in maximum width and the river meanders from side to side, cutting bluffs where it touches the valley walls. In some places the river had cut across these meander curves and ruined the lands on the concave side. In others,

where it had kept to its channel around curves, the land within them had been benefited. Lands situated just below a bluff that deflects the current toward the opposite side of the valley were usually protected from erosion and benefited by rich silt deposits. Bottoms on convex sides of river curves were almost invariably badly damaged by the scour from the swift current.

At Stony Point a rise of 10 feet covers the ordinary flood plain, but this is so broad that the extraordinary one, though only 6 feet higher, is never flooded. Where the maximum width of the two is half a mile or more this extraordinary flood plain would seem now to be passing into a fossil one—that is, one permanently above the reach of even the highest floods. There are abundant indications that the Holston as a whole is actively cutting its channel deeper or is degrading its course, so that any flood plain is constantly becoming higher above ordinary water level, and as a result ordinary flood planes are becoming extraordinary ones, and extraordinary ones in turn pass into fossil ones, while new ordinary flood planes are formed along the margin of the deepening channel.

The actual difference in elevation between these flood planes on any stream or on any portion of the same stream is determined by flood heights, and this is in turn dependent on stream slope and on the width of the channel and of the valley, and these are functions of the geology of the area and vary with the resistance of the rocks to the forms of erosion to which they are subjected. Differences in the interval between these several plains may be seen along the Holston or almost any other river in the region on which the valley width or the stream slope varies. As a rule they tend to lie farther apart on the upper reaches of the stream, where stream erosion is more active and the valley is narrower and flood crests are higher, and nearer together on the lower reaches of the stream, where opposite conditions prevail. Where the valley is locally constricted the interval is greater; where locally broadened it is less.

Just above the bend at Surgoinsville the bottom is three-fourths of a mile to a mile wide. One-half or one-fourth of this width is occupied by the ordinary flood plain and the rest by the extraordinary one, which here rises along a somewhat indefinite marginal line to a height only 3 to 5 feet above the ordinary one. Just on the point within the bend there is a large area which has recently been ruined and abandoned.

Near Chissolms Ford there were no signs of destruction, and, in general, where the course of the river remained straight the destruction of bottom lands was at a minimum; where it was most curved the destruction rose to a maximum.

At Spear's mill the sawmill, cabinet shop, and stave mill were destroyed, and much machinery was ruined by the flood of 1901. The high-water mark of 1867 is there 36 feet above ordinary water level. The high-water mark of 1901 is 3 feet 8 inches lower. The flood crest in 1901 then, though higher than that of any previously recorded flood on the Watauga, did not reach an equally abnormal height on the lower Holston, but was lower than that of the flood of 1867. The heaviest rains in 1901 were in the North Carolina mountains, and not on the headwaters of the Holston, in Virginia.

At Spear's mill the river turns westward, and for several miles cuts across the trend of the upturned Paleozoic rocks in a narrow valley that is bordered by a narrow flood plain. The bottoms on the small tributary streams in this reach were benefitted by the rich silt deposits left by the high water that backed up on them.

At Three Springs the valley widens and good bottoms occur. Some of these, especially those on the convex sides of bends, were badly injured. The average damage reached about 20 per cent. At Williams Ferry some farmers reported a damage of 50 per cent, and a few others have been benefited.

Just below Longs Ferry a farm in the bend, which the current swept across and ruined in 1867, had about made back again and was in cultivation in 1901, when it was badly damaged and again abandoned. From Longs Ferry to Noeton the river flows westward across upturned hard strata and is bordered by a narrow flood plain. Below Noeton the river turns southwest-

ward along softer rocks, and the flood plain again broadens. The river has there cut away some bottoms and has covered others with barren white sand.

Turleys Island has been badly damaged by washing and by covering with sand. About one-third of the farmers on the island report damage, some of which has been repaired by the settlings from later lower floods, so that scour or deposit is a function of flood height as well as of position with reference to stream curves.

From Turleys Island down to the mouth of the river, just above Knoxville, the damage was confined largely to points on the inner sides of bends. The current very generally swept across these and ruined them, but a few farmers whose lands were protected from the forces of the flood current reported that their lands were benefited. The average damage for miles along this lower stretch of the river will amount to about 10 per cent. The damaged lands were as a rule thrown out of cultivation in the hope that they would ultimately make back again, unless other equally high floods prevented.

NOLICHUCKY BASIN.

GENERAL FEATURES.

Nolichucky River is formed by the junction of Toe and Cane rivers about 8 miles east of the Tennessee State line, flows almost due north for several miles, then turns and flows in a general northwesterly direction to its junction with French Broad River just above Leadvale, about 7½ miles southeast of Morristown, Tenn. Its basin lies south of that of the Watauga, is about 75 miles long, and has an average width of about 25 miles, and, like that of the Watauga, comprises an upper part lying in the North Carolina mountains and a lower part extending into the great valley of east Tennessee.

The upper or mountainous part of the basin is itself part of a far greater basin whose surface forms the Asheville plateau. Beneath its general surface the many branches of the Nolichucky have cut gorges that are mostly sharp bottomed and steep sided and range in depth from a hundred to several hundred feet. Here and there rise above its general surface higher residual peaks or ranges that bound and delimit this basin from the neighboring basins. One of these ranges—the Black Range—includes Mount Mitchell, the highest peak east of the Rockies. To the southeast the basin floor rises gently to the crest of the Blue Ridge, but to the northeast it is separated from the Watauga basin by a steep-walled, sharp-crested divide that in Roan Mountain reaches a height of 6,313 feet. On the southwest are other bounding ridges that in places reach elevations of 6,000 feet or more and that separate it from the basin of French Broad River. To the northwest this upper part of the Nolichucky basin is separated from the lower or valley portion in east Tennessee by the high wall of the Unaka Mountains, through which the river has cut a deep and narrow gorge, 12 miles or more in length, whose sides rise precipitously in many places and in a short distance from the river reach elevations of 3,000 feet above its surface. West of this mountain wall, with its wild and narrow gateway, the river enters the great valley of east Tennessee, where its immediate valley is not so deep or so steep sided as in the upper mountainous area, and the mood of the river changes from an impetuous to a gentler one.

In the mountain basin the deeply dissected surface of the old Asheville plateau or peneplain is composed of ancient granitic or metamorphic rocks that are deeply decayed and in many places form rich soils. The numerous residual ridges rising above this old plateau level have been cleared to a considerable extent, and in many places, as, for example, about Burnsville and toward Bakersville, the plateau itself has long been cleared and farmed. Comparatively few of the farmed areas have been kept in grass. The culture is usually clean and the principal crops are corn and small grain. As a result the soils on many of the steep slopes have washed badly, and the destructive effects of mountain-side erosion and of floods along streams have probably been worse in this basin than anywhere else in the mountains. The detailed discussion of the basin begins with the lower or great valley portion of the river and follows it upward.

Where the Nolichucky enters the French Broad it is wide and shallow, and for a short distance above its mouth its current is broken by numerous islands. In the last few years some of these islands have been completely ruined by floods, and for 6 or 8 miles above the mouth of the river the farms on the bottoms have been damaged 10 to 20 per cent. Farther upstream, below Beulah, where the river makes some sharp bends, the damage was heavier, ranging from 15 to 25 per cent. In some places the alluvial soil was stripped down to the cobbles; in others sluices or runways were cut across the bottoms; in still others white sand was deposited on the lands.

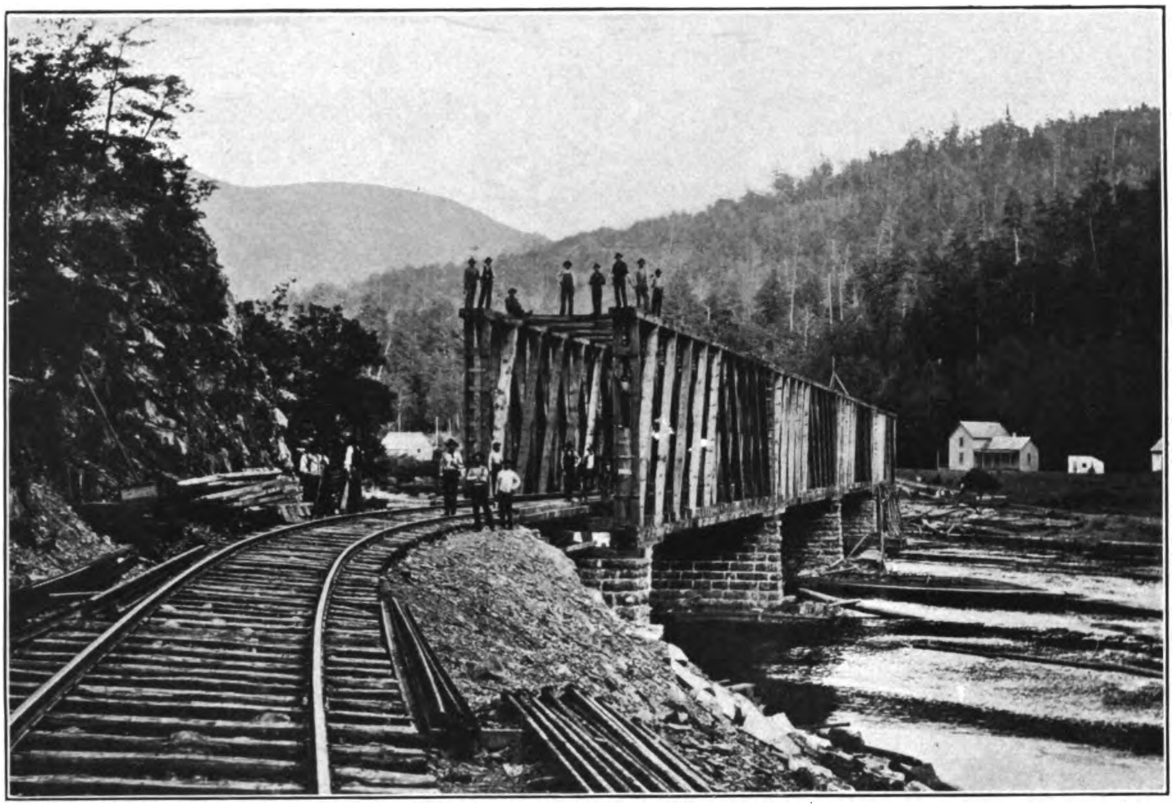
From Beulah up to Bird Hill, a distance of 5 or 6 miles, the valley opens out into a kind of flood-plain basin, at whose lower end, just below Beulah, the hills close in and constrict the river. During floods the lower portion of this tract has acted as a great settling basin and farms just above the lower end received deposits of rich sediment and were benefited by the flood. The current in the middle and upper part of this stretch, however, was strong enough to do much injury to lands on both sides. Above Bird Hill there is another similarly inclosed flood-plain basin, whose lower end was likewise benefited by the flood, but whose upper end was ruined. It was generally found that in broad basins lying above constricted valleys the flood waters were ponded by the constriction, and lands at the lower end of the basin were benefited instead of injured. In the reach above Bird Hill there is an ordinary flood plain of varying width, and 5 to 10 feet above it an extraordinary one, and the two appear in this relation along most of the course of the Nolichucky, although the relative width and the difference in altitude of the two flood plains differs from place to place, as controlling conditions vary. Commonly the lower flood plain is badly washed, gouged, or sand covered; the higher one is almost invariably scored by channels cut across it by extraordinary floods. When by the further down-cutting of the stream this extraordinary flood plain is finally abandoned, these stream-made scorings or flood channels guide the rainfall and determine the pattern of subaerial erosion forms that will develop upon it as a fossil flood plain. Above the extraordinary flood plain there are almost everywhere remnants of other old stream terraces that are still more or less covered with well-rounded cobbles. In one place there was a second old plain, 60 feet above the present ordinary flood plain; 50 feet higher there was a third; and a fourth occurred 50 feet higher still. These old terraces are usually cleared, and their steep scarps are in places eroded as badly as any lands in the region.

On the south side of the valley, at Allens Bridge, rounded cobbles occur on the general country level at an elevation of 220 feet above the present flood plain; 150 feet above the flood plain there is another prominent plain with rounded cobbles; and 100 feet above is another with a very heavy cobble bed. Still another old plain, whose surface is irregular and undulating, occurs at an elevation of 60 to 80 feet above the present plain and is well developed on the north side of the river, where it contains river sands and gravels, in places 10 to 12 feet thick and much indurated and reddened.

From Allens Bridge up the river for 15 or 20 miles the flood plain is relatively narrow and in many places a belt adjacent to the river was entirely swept away; in other places it was gouged or covered with sand. Islands, except those protected by timber on their upper ends, suffered severely. All bridges and ferries were destroyed. Some of these bridges were replaced or rebuilt, but these new bridges were also swept away, and other bridges have since been built.

From Henshaw, where a large mill was ruined, up to Brownsboro, all bridges were destroyed and the bottom lands were greatly damaged.

From Brownsboro up to Embree Furnace, a distance of 10 miles, the valley of the river is much wider than in many other places. The first bottom, or present living flood plain, ranges in width from 100 to 600 yards; the second or fossil flood plain, which is not now reached by even the highest floods, ranges in width from 1 to 2 miles and in altitude from 20 to 60 feet above the present flood plain, and has a surface that is quite irregular. Throughout this stretch of the river flood damages were very general and very heavy. On some farms the entire



A. RAILWAY BRIDGE OVER NOLICHUCKY RIVER AT UNAKA SPRINGS, TENN.

B. SAME PLACE AFTER THE BRIDGE AND PIERS WERE SWEPT AWAY BY THE FLOOD OF MAY, 1901.

See page 45.

tax assessment has since been removed; on many others 50 per cent has been deducted; and on practically all others 25 per cent reduction has been made. One farm, however, which lay in an area that was washed by an eddy, was so greatly benefited that its assessment was raised 25 per cent—a notable exception that serves only to emphasize the rule. Along a belt of varying width adjacent to the main channel of the river the alluvial surface was removed down to the bare rock. Farther from the river holes were gouged out, some of them of considerable size and depth; in other places immense quantities of white sand were deposited in a belt that extended usually from 100 to 200 yards from the main channel. In some places no attempt had been made to cultivate this barren white sand; in others a few melons were being grown on it. The great extent of this sand deposit made it an especially striking feature in this region. Its occurrence is easily comprehended when it is remembered that just above this stretch of broad valley the river emerges from its long and narrow gorge in the Unaka Mountains, in which its current had sufficient velocity to sweep everything before it. On emerging from the gorge the stream spreads across a broad flood plain and its velocity is immediately checked, so that it deposits large quantities of the coarser materials it carries. A sand waste of similar origin is shown in Plate VII, *A* (p. 22). At Embree Furnace the railway bridge and all other bridges were swept out and a 60-acre island was converted into a rock bar. Near Erwin the river has made considerable changes in its channel and is undercutting a portion of its flood plain.

At Chestoa a large lumber plant and dam had recently been swept away; at Poplar and at Unaka Springs railway bridges have been destroyed. Views of the bridge at Unaka Springs before and after the flood of 1901 are shown in Plate XIV (p. 44). Through the 12-mile gorge in the Unaka Mountain much of the railway track and roadbed were destroyed, and at present the rails and ties are anchored to the rocks by cables to prevent their loss when the roadbed underneath them goes out.

In Greene and Washington counties, Tennessee, along the west slopes of the mountains forming the North Carolina-Tennessee line the headwater portions of the many small streams tributary to the Nolichucky are being extensively logged. This logging is causing increased erosion, and the eroded material is carried down to the middle or lower courses of the steams where, because of the lower gradient, much of it is being deposited. These bottoms were once fertile and valuable corn and wheat lands, but by the present process of aggradation they have been made so much more difficult to drain that they are coming to be used for meadows and grass. The owners of the many small mills situated on these streams assert that the water power now fails much more frequently in dry weather during late summer and fall than in former years, and that low water comes earlier, goes lower, and lasts longer than formerly. They attribute this change to the clearing and logging on the headwaters of the streams.

Hollow Poplar Creek has comparatively little flood plain except near its mouth and does not seem to have suffered much damage. Its basin has not been cleared to any considerable extent and shows no traces of active erosion. Much of the soil is derived from quartzite and is poor and sandy.

From Poplar to Huntdale the Nolichucky flows in a steep-walled gorge 300 or 400 feet deep, whose sides are, as a rule, rough and almost entirely uncleared. Along the stream itself there are no bottom lands worthy of mention. Above the top of the gorge the higher slopes are gentler and soon reach up to the old Asheville Plateau level, where farms are numerous. Where they have not been well cared for the fields usually show distinct evidences of active erosion.

TOE RIVER.

Above Huntdale the gorge-like character of the river continues beyond the junction of the North and South Toe, although the gorge gradually decreases in depth upstream. A view of this part of the Nolichucky Gorge and of the Asheville Plateau surface beneath which it is cut are given in Plate XV, *A* (p. 46).

The North and the South Toe flow in similar gorges for a number of miles above their junction. In fact only near their headwaters do their gorges entirely disappear and their valleys open and almost merge into the old plateau surface. No important flood plain appears throughout the gorges, though here and there narrow strips occur, especially on the concave side of bends and near the mouths of small tributaries. These flood-plain areas have been much damaged by flood. In some places the soil has been entirely swept away, leaving the bare rock; in others it has been buried beneath sand and cobbles.

CANE RIVER.

From Huntdale to the mouth of Bald Creek, Cane River also flows in a sharply cut gorge, 300 or 400 feet deep in its lower portion and 200 or 300 feet in its upper. In this distance there is almost no alluvial land, and the steep valley walls are but little cleared. Back from the brink of the gorge the old plateau slopes are more gentle and in places are cleared and show signs of considerable erosion. Some of the fields have been abandoned.

Bald Creek is the only important tributary along this portion of the Cane. Its narrow flood plain and steep-sided valleys slopes are generally cleared and in cultivation for a distance of 300 or 400 feet from the stream bed. The higher slopes and the entire upper portion of its basin are in original forest, which is now rapidly being lumbered and carried by tramway to Huntdale for shipment.

At the mouth of Bald Creek the gorge opens into a wide valley in which there is a broad fertile flood plain that stands about 8 feet above ordinary water level. A belt 150 yards wide adjacent to the stream has been denuded of its soil, and attempts have been made to protect and reclaim the devastated area by building rock walls and cribwork and by planting balm of Gilead trees over the denuded area as well as along the undercutting banks. From this point upstream to the vicinity of Athlone there is comparatively little bottom land. Along Cane River 50 to 75 per cent of the slopes are cleared and in many places show erosion of the worst type. The rocks are fine-grained gneisses and are deeply weathered into soils that are generally micaceous and loamy and easily eroded.

As a rule the valleys of all of the creeks and other small tributaries of the upper Nolichucky are receiving from their bordering hillsides more waste than they can remove. This waste is accumulating along their courses, filling their channels and spreading over the bottoms and rendering it impossible, without expensive ditching, to drain these once fertile and valuable lands. In many places these bottoms have been abandoned and are growing up in rushes and willows, so that they do not now furnish even good pasture.

On Bald Creek the hill slopes are extensively cleared and in many places badly eroded.

Hinton Creek shows badly washed uplands and its bottoms have been greatly damaged by the sand and clay washed upon them from the eroding slopes.

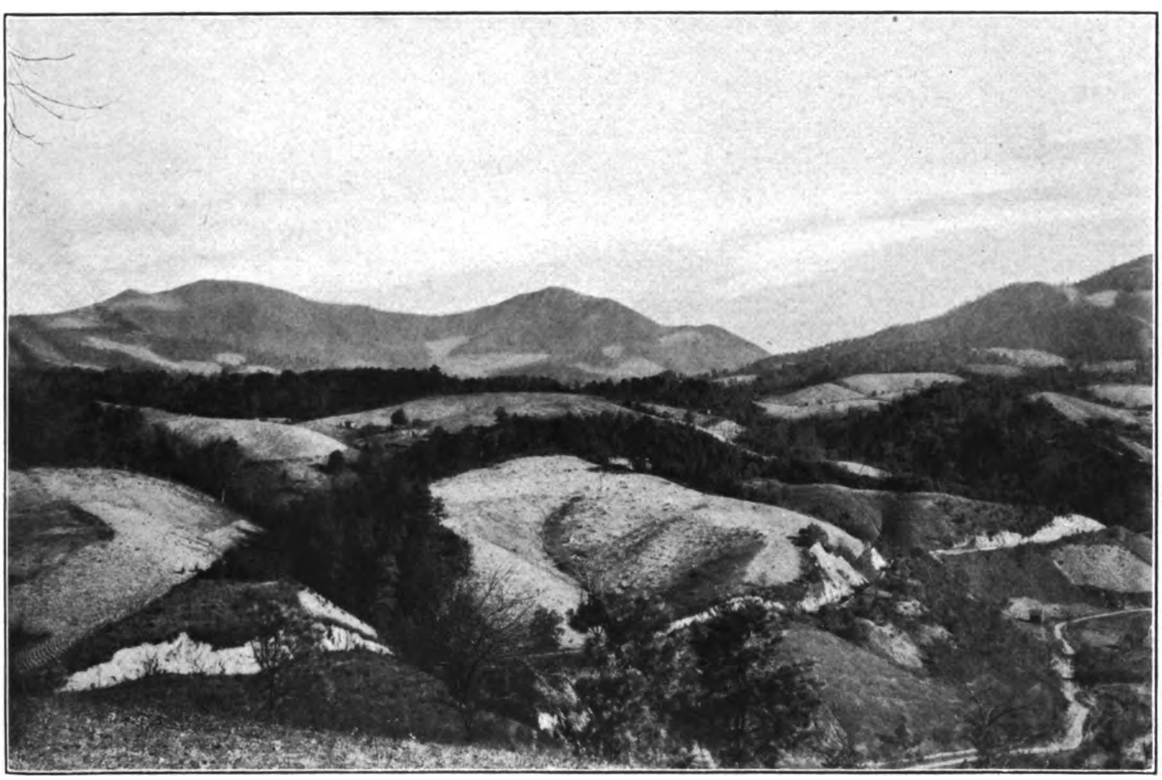
Jack Creek basin has, perhaps, the most cleared land and also the worst eroded land to be found in the entire region. Nearly all of the erosion has occurred in recent years.

Though the severe erosion of this region is due primarily to the steepness of the cleared slopes, the heavy rainfall, and the nature of the soil, much of it is due also to the reckless system—or want of system—of cultivating these slopes, for most of them have been planted year after year in corn or small grain. Farmers are now beginning to realize the danger of this practice and are putting more of their mountain-side fields into clover and grass, so that grazing and haymaking are becoming important industries. It is only by some such practice that these lands can be saved and at the same time used for agriculture. A better and safer use of many of these slopes would be to reforest them.

Above Athlone, Cane River flows in a steep-sided valley in which there is a heavy torrential flood plain that is 100 to 400 yards wide and that stands in most places between 3 to 6 feet (locally as much as 8 feet) above ordinary water level. This flood plain has a rather undulating surface and, although for the most part fertile, is in places composed of micaceous sand and

A. NOLICHUCKY GORGE CUT INTO THE ASHEVILLE PLATEAU.

See page 45.



B. A WELL-DISSECTED PART OF THE ASHEVILLE PLATEAU.

Residual mountains in the distance. See page 50.

rounded cobbles that make an exceedingly poor soil. It is practically all cleared and in grain or grass. In its lower portion there is a stream-swept waste zone of bare cobbles, 50 to 100 yards wide, and in places along the edge of this cobble zone the stream is undercutting the flood plain. Rock walls and cribbing, such as are illustrated in Plate VIII (p. 24), have been used at many points to protect the lands from further erosion.

In the upper part of this basin the slopes retain their primeval forest cover. The stream flows with a clear, swift current, the flood-swept cobble zone disappears, and the flood plain itself becomes narrower, and above Big Tom Wilson's is but little cleared. It is still a natural trout stream. Its flow is fairly constant throughout the year, and the mills somewhat lower down do not lack water during the dry season in late summer and autumn.

LITTLE CRABTREE CREEK.

About Burnsville, which is practically on the level of the old Asheville Plateau surface, the uplands and the slopes down to the drainage-ways have in many places been cleared for years and present all too frequently the bare red-clay surfaces that indicate the entire absence of soil. Many of these fields are deeply gullied; in others bare red areas have taken the place of the former gullies. When the fields have reached this stage it is almost impossible to reclaim them in any reasonable time or at any outlay which would be warranted by their value. Many of them are abandoned as worthless and remain indefinitely as bare red-clay spots on the face of the country; others are turned into pasture lands, and the trampling of hoofs, together with the too close grazing to which they are usually subjected, effectually prevents their reclamation by plant growth; others, from which cattle are kept off, eventually grow up in briars and broom sedge; a few sprouts of locust, pine, or persimmon take root, and in several generations a forest cover once more becomes established. At intervals, however, prominent bare-sided gullies may remain, and these slowly undermine the forest cover and prevent the land from ever again being used for agriculture.

In some places about Burnsville the aggrading flood plains have been extensively ditched in the effort to lower the subsurface water level and keep the lands dry enough for the culture of corn and small grain. Many of these ditches are filled with sand and gravel during a single rain. While examining the region just east of Burnsville the writer noticed that the rain of the previous day had in many places washed a foot or more of sand and clay over the roadbed. In one place a loaded wagon, left by the roadside when the rain began, had been buried almost to its axles by mud washed from the hillside above. The roadside ditches were entirely filled, and in many places extensive areas of bottom lands were covered with muddy alluvial fans and the growing crops of 24 hours before were buried and utterly destroyed. So rapid had been the erosion that in a few hours fences had been buried, on their upper sides, to their tops. This particular rainfall was not extraordinary in amount but had come soon after most of the fields had been plowed, so that a considerable layer of loose material was ready for rapid removal. Results of this kind are liable to happen at any time under the conditions that prevail so widely in the Nolichucky basin and plainly teach that such slopes should not be farmed but should be held in timber or grazed.

East of Burnsville, the tributaries entering Little Crabtree Creek from the north have been especially destructive, spreading alluvial fans of rock and sand in many places well across the once good bottom lands on each side of this small stream. When seen, these tributaries were still muddy from the heavy rainfall of the day before and the muddiness persisted for several days after the rain had ceased and the streams had fallen again to their ordinary level, indicating that large quantities of very fine clayey material were still being carried. In this respect these streams showed decided contrast to the tributaries of the South Toe River, which flow northward from the steep wooded slopes of the Black Mountains. When the tributaries of the South Toe were examined it had been raining almost steadily for 24 hours or more, and although the streams were much swollen they were practically clear; they flowed from basins

entirely forest covered and were carrying almost no sediment. This contrast between the amount of sediment carried by streams flowing from cleared and those flowing from wooded basins was observed time and again throughout the entire region, and it would be exceedingly interesting, were it possible, to determine quantitatively the relative amounts of silt carried out during the year by streams of these two types. The difference is perfectly constant and characteristic and must quantitatively be very considerable.

The rocks along Little Crabtree Creek, as elsewhere in the Burnsville region, are deeply decomposed micaceous gneisses and granite, which erode readily when once the forest cover is removed.

BURNSVILLE SOUTHWARD TO MOUNT MITCHELL.

Bowlens Creek, which enters Cane River about a mile south of Burnsville, has a torrential flood plain 200 to 300 yards wide along its lower course, and 100 to 200 yards wide along its upper course. This plain has an exceedingly irregular surface, due to the choking and abandonment by the stream during floods of certain portions of its winding channels and the forced cutting of new channels before the flood plain had been cleared of timber. Many of the wooded flood plains of the small streams, especially of those on the east slope of the Black Mountain range, show this process actively in operation. Rafts form at favorable places on the wooded flood plain and the stream cuts a new channel and abandons the old. This is especially true where the descent of the stream is steep and its consequent velocity is great. The materials of this Bowlens Creek flood plain are heterogeneously mixed sands, clays, and cobbles. The soil is fertile and the principal damage to-day is that caused by the constant shifting of channel due to the high velocity of the stream and its tendency to undercut its banks. The high slopes of the basin are wooded and so are not damaged.

SOUTH TOE RIVER.

From Micaville southward to the ford of South Toe River above Celo much of the road is on the well-dissected plateau level. The region is generally rough and for the most part wooded, but there are a few scattered farms, some of which have been cleared too recently to show pronounced erosion. Some fields that were cleared long ago have eroded badly and are abandoned. The river itself flows in a narrow trench, which is generally uncleared.

Along the upper part of the South Toe the valley broadens and the stream is shallow and clear, with a swift current that in most places flows across and is actively eroding the upturned edges of the ancient gneiss and schist. It is bordered by an ordinary flood plain that stands 4, 6, or locally as much as 8 feet above ordinary water level. At and just above water level this plain consists of cobbles, which are overlain by 3 to 5 feet of silt and sand. Much of the sand is too poor to sustain more than a scanty vegetation. This ordinary flood plain, though about 300 yards wide, is badly gouged or cut by flood channels and is cultivated in but few places. At a vertical distance above the ordinary flood plain that varies considerably but in many places reaches 15 to 20 feet there is an old, high-level flood plain or terrace, whose surface is undulating from ancient flood channels that are similar in origin to those on the present flood plain. This terrace is largely cultivated and many houses are built upon it. It had been considered safe from all danger of overflow, but during the floods of 1901 and 1902 it was covered in numerous places.

Above the mouth of Rock Creek the river is slowly shifting laterally as it cuts down and is forming a sloping or beveled flood plain, only the lower edge of which is ever covered by floods. This flood plain is cleared in many places but the land is mostly sandy and poor and is now largely in pasture.

On the headwaters of the river there are very few clearings, the slopes being covered with virgin forests, especially on the Black Mountain side. Some lumbering has been done in this region, the product being hauled by wagon to the railway at Old Fort. Most of the timber, however, remains standing and some of it is held in large tracts.

NORTH TOE RIVER.

The country about Sevenmile Ridge, Crabtree Creek, eastward to the North Toe, up its basin to Elsie, and eastward to the Blue Ridge is largely in forest, except along the stream ways, where narrow flood plains occur, either continuously or in broken strips. The uplands are generally poor and these narrow flood plains are by far the best lands of the region. Some of the best timber has already been removed, but renewed activity has been manifested in lumbering since the building of the Carolina, Clinchfield & Northern Railway to Spruce Pine and beyond. In some places, notably on Crabtree Creek and along North Toe River, the alluvial bottom lands have been much damaged in the last few years by floods, and those who are familiar with the region say that these floods are rapidly becoming more severe. The average damage to bottom lands in this section during the last few years is 25 to 35 per cent.

FROM CLOUDLAND TO MAGNETIC AND BAKERSVILLE.

From Cloudland the road to Magnetic follows the top of Roan Mountain for about 2 miles and then rapidly descends the western slope, which is densely wooded down to an elevation of about 3,800 feet, where fields begin. A short distance below this level 75 per cent of the mountain side has been cleared, though the slope in places is exceedingly steep. Fields that have been kept in grass have been measurably safe from erosion, but on others the soil, which is a compact red clay derived from the weathering of diabase, has been badly eroded, leaving a maze of steep-sided gullies where it was thick and an area of bare rocks where it was thin. On the headwaters of Big Rock Creek above Magnetic there are many mountain-side clearings, and the flood plain of the stream has been much damaged by recent floods. The owner of the mill at Magnetic says that he can now run only about half the machinery during seasons of low water that he once could.

Below Magnetic the creek cuts across alternate belts of diabase and granite. In the areas of diabase it occupies a narrow, rocky gorge having steep walls, which in many places are cleared and have eroded badly; in the granitic rocks its valley walls have gentler slopes and it shows a tendency to develop flood plains. These granitic areas have a more porous soil and are not washing as badly as those in the diabase, but many of the flood-plains lands have been ruined by débris washed down upon them from the narrow, sharp-bottomed diabase gorges above. Some fences on hillsides are banked to the top on the upper side with soil washed from the field above, and in some places new fences have been built on this filling. Practically every mill and dam below Magnetic was swept away by the floods of 1901 and 1902.

On both Big and Little Rock creeks every milldam pond examined was full or almost full of sand and clay, so that it had become valueless.

The Asheville Plateau is strikingly developed in the region about Bakersville at elevations of 2,600 to 2,700 feet above sea level. Cane Creek and its upper tributaries have cut 200 to 300 feet below this old level and 50 to 75 per cent of the remnants of the plateau and the slopes from it down to the present streams are cleared. The rocks are granitic or gneissose and in many places are micaceous, so that the deep soils that have been formed from them usually erode easily. During the flood of 1901 Cane Creek destroyed practically its entire flood plain throughout a distance of some 10 miles. At Bakersville a number of houses, mills, and dams and a quantity of logs and lumber were swept away and several lives were lost. Roads and bridges in the region were almost entirely destroyed and had to be rebuilt at great cost to the county. Some of them had not been replaced in 1904.

The stream now flows practically on its flood-plain level, and the waste of sand and cobbles is almost without drainage so that the land would be unfit for cultivation however fertile it might be. Before the recent change in stream regimen that has resulted in destructive floods these lands were the best in the region. The stream is now constantly aggrading and shifts its position with every flood. In some places land owners have attempted to restrain it by

building walls and planting trees, such as willow, cottonwood, and balm of Gilead, but for the most part they have ceased all attempts at reclamation and have abandoned the lands as worthless. People in the region are generally aware of the danger that the clearing of steep slopes has brought upon them and some attempts have been made to check the evil.

FRENCH BROAD BASIN.

GENERAL FEATURES.

The French Broad rises in the Blue Ridge and flows northwestward across the entire width of the Carolina mountains and halfway across the great valley of East Tennessee to its junction with the Holston near Knoxville. Its basin, 45 miles wide by 90 long, lies between the Nolichucky basin[a] on the northeast and the Little Tennessee basin on the southwest, from both of which it is separated by mountain ranges, some of whose peaks rise to elevations of 5,000 or 6,000 feet above sea level.

The basin is divided transversely by the high range of the Great Smoky Mountains, which form the North Carolina-Tennessee line, into a smaller, lower part lying in the valley of east Tennessee, and a larger, upper part, 60 miles long by 45 miles wide, lying wholly in the North Carolina mountains and forming an elevated plateau, bounded on the northeast, northwest, and southwest by high mountain walls, but rising gently to the crest of the Blue Ridge on the southeast and there overlooking the steeply sloping, eastward-facing scarp of this so-called ridge and the Piedmont Plateau, which lies at its base. This upper part is known as the Asheville Plateau.

UPPER FRENCH BROAD BASIN.

GENERAL FEATURES.

The plateau-like floor of this old river basin slopes gently northwestward. From its bounding mountain walls spurs project into the basin, and at numerous points within it isolated residual peaks rise above its general level. Below this level the French Broad has cut a channel to a depth ranging from a few feet along its upper course to 400 feet or more at the place where the river cuts its way through the Great Smoky Range, which forms the western rim of the basin. The larger tributaries have, in like manner, sunk their channels beneath this general surface, and with their many branches have cut the once continuous plain into a maze of rounded, domelike hills or subacute ridges such as are illustrated in Plate XV, *B* (p. 46). The smaller tributaries have not been able to keep pace with the rapid downcutting of the French Broad, but flow practically on the old plateau surface and descend to the level of the French Broad, generally in the last mile or less of their course, in a series of rapids or falls, so that they may more properly be called hanging valleys. The rocks of almost the entire basin are granites and gneisses, which are nearly everywhere deeply decayed. Only along the sides of the steeper and deeper stream gorges do bare rocks appear. Elsewhere the surface is mantled with a deep soil, usually of red clay. The soils of this basin are among the most fertile in the entire mountain region. It was one of the earliest-settled areas and has been cleared longer and farmed more extensively than perhaps any other stream basin in these mountains. Disregarding the residual peaks and ridges that rise steeply above the plateau surface, more than 50 per cent of the basin is cleared, and some of the minor valleys or parts of the basin may be more than 75 per cent cleared.

Grass does not seem to flourish in this basin as well as it does nearer the Virginia line at the same elevation, probably because the basin is somewhat warmer and dryer by reason of its more southern position and exposure. Therefore a smaller proportion of the cleared land is in grass than in the Watauga Valley, for instance. In places, however, especially on the higher cleared slopes, grass seems to thrive well and is extensively grown. The principal crops are corn, buckwheat, and small grains. Apples are grown in considerable and increasing quantities. Some years ago tobacco was an important crop, especially in the region north and

[a] The Nolichucky, though a tributary of the French Broad, is discussed separately. See pp. 43-50.

northwest of Asheville, in the basin of Ivy River and its tributaries. The destructive effects of the clean culture required by this crop were quickly manifest, and, although it has been abandoned almost entirely, the erosion induced by its cultivation has continued to injure the lands where it was once grown and has caused profound changes in the streams.

Many of the hillsides sloping from the old plateau level down to the streams throughout the entitre French Broad basin have been badly gullied and in places abandoned. Here and there the soil has been entirely stripped off in sheet fashion, leaving bare red-clay hills.

FROM ASHEVILLE EAST TO SWANNANOA GAP.

The valley of the Swannanoa, one of the principal tributaries of the French Broad, is relatively wide, its bounding mountain walls standing in places 1 to 2 miles back from the stream itself. The channel of the Swannanoa is broad and shallow and is usually much filled with sand and gravel. Its flood plain rises but a few feet above stream level and a considerable part of it has a rather porous sandy or gravelly soil. In some places this flood plain is only a few rods wide; in others, as at Swannanoa, it is several hundred yards wide. Its narrower portions have been cut into holes or covered during floods by sand and have thus been practically destroyed, and along most of its broader parts a belt near the stream has been injured in like manner. Its surface is so low that a rise of only a few feet covers it with flood water, and within the last few years floods have become so frequent that the production of crops on this flood plain has become very uncertain and, as a consequence, much of it that was formerly successfully cultivated is now growing up in weeds and bushes.

Where it is narrow this flood plain is bordered, at an elevation of 15 to 20 feet, by a fossil flood plain which is safe from inundation by even the highest floods, whose undulating surface is covered with stream-borne materials and whose soil is usually of good quality. It is very largely cleared. Above this old flood plain level, low, gently rounded or flat-topped hills rise 100 to 150 feet, their tops marking the position of the surface of the old Asheville Plateau. Their lower slopes are steep and subject to severe erosion when not properly cared for. Fifty per cent or more of the entire valley is cleared and only the second bottom and the flat plateau surface are safe from destructive erosion.

The lower slopes of the bounding mountains, especially on the south side, are cleared at intervals up for a short distance from the valley level. In a few places the higher slopes show isolated mountain-side fields, but most of them are in dense forests.

At Black Mountain station the river has a broad, beveled plain rather than a flood plain, and this has not been eroded.

The North Fork of the Swannanoa has a broad valley, much like that of the upper part of the main Swannanoa, and it is cleared and has been eroded in much the same manner. Its bounding mountain walls are heavily forested. Like the other mountains of the Swannanoa basin, they are accessible to railways and have therefore been stripped of much of their best timber. In the lumbering operations many runways have been formed, which have caused considerable erosion on their steep slopes and consequent damages by floods along the streams.

Beetree Creek is largely torrential and has very narrow bottoms. Its bounding slopes are cleared for only short distances up the mountain sides.

Bull Creek has less descent and has broader and better bottoms, only the upper parts of which have been greatly eroded. Some lands near the head of the main creek have been abandoned within late years because of damage by floods. On Elk Mountain side some of the high slopes and much of the mountain top have been cleared, but the clearings are kept in grass and are thus protected from erosion.

The valley of Gazes Creek is perhaps 60 per cent cleared, and there is more than the usual proportion of clearings on the steep slopes of the Swannanoa Mountains. These high mountain lands, like those on the Elk Mountains, are protected from erosion by being kept largely in sod.

Throughout the Swannanoa basin there are many small streams at whose head are coves large enough for individual mountain farms. When first cleared these lands are fertile, and

they do not erode badly until the humus has been destroyed; but when long cultivated, unless carefully guarded, they are subject to erosion, and in many places they have been abandoned as worthless.

FROM ASHEVILLE SOUTHEASTWARD TO FRUITLAND, EDNEYVILLE, THE BLUE RIDGE, AND HENDERSONVILLE.

In the Busbee Mountains there are some clearings but no marked signs of erosion. The soil is sufficiently porous to prevent serious washing. On the steep slopes near the head of Caney Creek and of its tributaries there is much cleared land that has washed badly in the last few years, and floods on the main stream have risen higher than usual and been especially destructive to the bottoms in the middle and lower portions.

On Hoopers Creek the soil is as a rule thin, and the lands have not been extensively cleared except in the small coves at the heads of the various tributaries around its basin. The channel of the main stream has in recent years deepened because many of the fences, with their obstructing water gaps, have been removed in consequence of the adoption of the stock law. As a result, flood water is now carried away more effectively than formerly and floods are not so destructive.

Fruitland, in the valley of Clear Creek, is situated on the rolling surface of the old Asheville Plateau. The stream here has not cut deeply below this old surface, so that the slopes are gentle, and erosion may be easily prevented. The rock in this region is deeply decayed porphyritic granite-gneiss, which weathers into a porous soil that does not suffer much from erosion. There is no reason why this area may not be entirely cleared and farmed without injury if proper precautions are taken. On the mountains around Fruitland there are a few clearings, especially on the domelike crests and gentler upper slopes; the lower slopes are steep and are almost entirely wooded. Floods on Clear Creek are reported as having been worse for the last three years than previously, and in some places bottom lands have been damaged; in other places, however, they have been improved, so that the average condition along this stream is about as it has been for years. Just west of Edneyville there are some steep cleared fields that show considerable erosion, which was said to have occurred within the last three years.

The entire region from Fruitland to Edneyville and southward to the Blue Ridge and Hendersonville is characterized by gentle slopes and may be cleared almost anywhere without serious danger of erosion. Mud Creek and its tributaries flow for the most part in broad, flat valleys and are either aggrading their channels or at a balance between cutting and filling.

Near and above Hendersonville, Mud Creek and its tributaries have broad, swampy flood plains and the stream channels are practically on the surface. These flood plains are grazed to some extent, but are too wet for cultivation. In most places they are bordered by a fossil flood plain with an undulating surface that is covered by rounded gravel and cobbles. At Hendersonville this old terrace is 20 to 30 feet high and part of the town is built upon it. Above Hendersonville it is usually from 30 to 60 feet high and includes nearly all of the cleared land of the upper portion of Mud Creek. The mountain sides there are rarely cleared.

The valley of Crabtree Creek, to the west, has a narrow flood plain bordered by an undulating terrace plain 30 to 50 feet higher, both of which are cultivated; the mountain slopes on either side are almost entirely forested. The stream channel is deep and the current swift, so that flood waters are quickly carried away and do little or no damage.

The mountain slopes and some of the knobs south of Crabtree Creek show considerable areas of rounded, precipitous, bare, granitic rock, and much of the wooded area has an exceedingly thin soil layer above the hard granite surface. A large part of this wooded area is made up of steep slopes; and deforestation, which, fortunately, has not yet begun here, would soon convert much more of it into bare rock surface, for when once the cover of vegetation has been removed from these domelike granitic masses there is nothing to hold the thin soil layer on the smooth surface of the underlying rock. When once removed by erosion it would be the work of ages to disintegrate the granite sufficiently to produce a second soil cover.

Just south of Grange, Little River flows from a narrow rock-bound gorge out upon a broad, somewhat sandy, but comparatively fertile flood plain, all of which is cleared and farmed. The stream has recently cut channels across portions of this flood-plain surface, and here and there has been undercutting its banks. At a number of places rock walls or brush and earth embankments have recently been built to protect the lands from floods, which have not yet been so disastrous as they will be when the upper part of the basin of Little River has been further cleared. More or less logging is being done in the area, and on steep slopes runways for flood waters are increasing in number; and as they become converted into rills they deliver storm waters and rock débris with greater rapidity to the main stream ways. Above this there are no important bottom lands on the river north of Sheep Mountain; south of it up to Cox's store there are some comparatively large separate tracts. Above Cox's store the flood plain is continuous, has an average width of 100 to 250 yards, and is fertile. Throughout this distance the river is not materially injuring the bordering bottom lands. Its channel is comparatively deep and has not been filled by sand and, as a rule, the adjacent lands have not been cut away nor covered with sand. The bordering slopes are cleared only in small areas and at considerable intervals for a distance of 100 to 200 yards up from the bottoms. The higher and more remote slopes are entirely wooded. Indeed, away from the immediate stream ways there is comparatively little clearing anywhere in Little River basin. At the time of examination the river was considerably swollen but the waters were almost clear. It is a good example of a stream still fairly well protected by natural forest cover.

Carson Creek flows in a narrow, rocky gorge in a basin that is almost entirely forested. When examined it was much swollen by several days of heavy rain but was nevertheless almost as clear as crystal.

BETWEEN ASHEVILLE AND LAKE TOXAWAY.

At the mouth of Carson Creek the French Broad has a flood plain averaging a half mile or more in width. The stream itself is 100 to 150 feet wide, and flows with a swift current between banks whose exact height could not be determined, but which were perhaps between 6 and 10 feet. At the time it was examined the stream was considerably swollen from intermittent but sometimes heavy rains that had continued for a week.

Almost the entire basin of the river above this point is forested and the absence of a sudden and destructive flood at any time during the week furnished a good example of the slowness with which the run-off from these continued rains had been carried away by the river. On the contrary the rise of the river had been slow, and residents reported that it would take some days for the water to fall to normal stage again after the rain had ceased. The bottoms nowhere along the stream, either above or for a number of miles below, showed any signs of material injury from floods, and the reports of farmers in the region agreed with the observations. The lands are not being injured by floods, and for explanation one needs but to turn to the forested slopes of the entire basin.

Above Rosman the many branches into which the river separates are bordered by very little bottom land and are but little cleared; the steep slopes are in forest, practically untouched by the ax until the recent building of a railway to Toxaway. Now lumbering operations have been begun, and before many years conditions will change and the rich valley lands will begin to suffer from the floods resulting from the cutting of the forests, the erosion of the steep slopes, and the filling of the stream channels. Between Rosman and Lake Toxaway there are a few plateau clearings, but the area is so small that the total erosion is negligible.

In the trip from Rosman down the west side of the French Broad Valley to Brevard, taken on the following day, the many tributaries flowing from the wooded mountain slopes on the west were still much swollen, though the rains had ceased 24 hours before. A few of them were slightly discolored by decaying vegetable matter, but most of them were perfectly clear. Practically the only discoloration in the French Broad itself was due to decaying vegetable matter. It is carrying exceedingly little silt in this upper portion and its basin is being eroded at an almost infinitely slow rate. These conditions can not long be preserved if the reckless

cutting of timber is once started here as it has been in almost every other stream basin of the region.

Davidson River flows from the Pisgah Range southeastward into the French Broad just below Brevard. Near its mouth it is 75 to 150 feet wide, is shallow, and flows swiftly over gravel and cobbles. Here and there along its way are gravel bars and tree-grown islets. Its banks are but 2 to 4 feet high, and its flood plain has an average width of a fourth of a mile and is level, but is composed of sands that are poorly adapted to agriculture. So swift is the current of the stream that flood crests can reach no considerable height, as is indicated by the lowness of the flood-plain surface. The stream has not materially injured this flood plain. The hills rise abruptly from the edge of the flood plain and are entirely wooded. The soil is produced by the weathering of a micaceous schist in most places and is relatively poor.

Avery Creek, a branch of Davidson River, has for about 2 miles up from its mouth some narrow flood-plain areas that, with the lower slopes, especially on the south side of its valley, had once been cleared, but are now within the Pisgah forest reserve of Mr. G. W. Vanderbilt, and are being reforested largely by the natural growth which is springing up abundantly everywhere. The middle and upper part of the basin of Avery Creek is forested to the summits of the surrounding mountains. At Bennett Gap and just beyond, on the south slope of the ridge, there are a few old fields that show some erosion but are now being reforested. From this elevated viewpoint southward and westward the entire region is an unbroken forest, no clearings whatever being visible.

In the Pink Bed country the surface is generally level, and the porous, coarse-grained granitic soil has but little natural fertility, and in some places is dry enough for the growth of pines. There are no large clearings in this region. The streams run with clear currents, but are discolored in some places by swampy vegetation. From the Pink Beds northeastward through Yellow Gap to Rocky Fork of Mills River the country is an unbroken forest, with usually deep, rich soil and an excellent forest growth. Some of this has been culled of its best timber, but the logging was under forestry supervision, as, indeed, is the entire Pisgah reserve, so the conditions there are excellent throughout. Fireways and other means for protection have been liberally provided.

On Rocky Fork of Mills River clearings along the narrow flood plain begin within a mile from the point where the road reaches the river and gradually widen downstream until they are from one-fourth to one-third of a mile wide and contain some excellent lands. The river flows with rapid current over a bed of gravel and cobbles, with a channel 3 to 4 feet below the flood-plain level. The flood plain, like that of Davidson River, is flat and the stream is clear. Flood crests are low and there has been practically no flood damage.

In this region low, rounded hills rising to a common elevation, 100 to 120 feet above the flood plain, appear as the valley widens. They are remnants of the old Asheville Plateau surface and are generally cleared. In places their steep slopes show the erosion forms elsewhere typical of the steep slopes of the dissected Asheville Plateau. They are largely kept in grass, however, as are also the lower slopes of the higher ridges where cleared, as they are in places up 100 or 200 yards, so that there is comparatively little erosion.

From Angeline northward to Sandy Bottom the road is mostly on the rolling surface of the Asheville Plateau. Sixty per cent of the land has been cleared, but much of it has lost its original fertility through careless farming, and has been cut to pieces with gullies and abandoned. The higher knobs to the west of the road are being cleared in their upper portions and are being put in grass. All the land is rather thin and will need careful proteetion to prevent erosion.

From Stradley Mountain to the southeast and east less than 50 per cent of the plateau appears to be cleared; to the northeast about 50 per cent is cleared; and to the north and northwest 60 to 70 per cent is cleared. The peaks that rise above the plateau surface, such as Spivey and others northwest of it, are 40 to 50 per cent cleared on the sides visible from Stradley. This area is mostly in grass and shows very little erosion. The rounded hills of the plateau surface are badly scarred in numerous places by gullies and have been abandoned.

They appear as bare red-clay areas, visible for long distances in their contrasted setting in the green of summer field or forest. Near Asheville the proportion of cleared land becomes greater, but agricultural conditions have also improved and there is less erosion than is usual in this region in areas having similar topography.

BETWEEN ASHEVILLE AND HOT SPRINGS.

Between Asheville and Hot Springs the French Broad flows in a narrow, steep-sided gorge, which is about 200 feet deep at Asheville, but gets gradually deeper until at Hot Springs it is approximately 400 feet deep. Throughout most of this distance the walls of the gorge are wild and rocky and are covered with a scant forest. Here and there, where they are composed of granite or gneiss, they have weathered so as to produce a fertile soil. In such areas they are largely cleared, though they are entirely too steep for most agricultural uses. Many of these areas have not been properly cared for, but have been worn-out and are abandoned.

The river is 100 to 300 yards wide, has a rapid descent, and flows over exposed ledges of rock throughout this part of its course. Just below Asheville it is bordered by a beveled flood plain, which is in places 200 or 300 yards wide, but as a rule is found, in any given stretch, on but one side of the river. The portion of this flood plain nearest the river has in recent years been cut to pieces by floods or covered with sand, and its outer, higher portion, near the gorge wall, has been badly injured by overwash from the steep slope above wherever the slope has been cleared. Most of this flood plain just below Asheville has been abandoned and now makes only a very poor pasture. Farther down the river the flood plain soon practically disappears, and in much of the distance to Hot Springs there is scarcely room in the bottom of the gorge for the river and the railway. In some places a road lies along on the river bank, but in others it has been forced to climb out of the gorge to the old plateau level.

There is abundant fall along the entire distance, but the development of water power has been attempted at only a few points, and is, in fact, practically prevented by the slight elevation of the railroad above ordinary water level. Power has, however, been developed just below Asheville and also at Marshall. In recent years the scant flood plain, the highway bridges, and the railway tracks have been much damaged by floods, the railway being the chief sufferer, though at Marshall a number of houses were carried away.

All the tributaries, including even Ivy River, flow in narrow, steep-walled, and usually rocky gorges in their lower courses, and enter the French Broad by a series of rapids or falls. One must go some distance up their channels to find open valleys and flood plains.

The country back on either side from the brink of the French Broad gorge is a rolling or hilly upland, once a part of the Asheville Plateau surface, but now deeply dissected. Many of the hills near the river are exceedingly steep, but those farther back from the river, down to a point below Barnard, have gentler slopes.

The valley of Shut-in Creek is in an area of quartzite, shale, and limestone. The land is rough and poor. The bottom lands are narrow and of no great value, and the hillsides are only slightly cleared. The land is soon worn out when once the humus has been destroyed.

Spring Creek enters the French Broad at Hot Springs, and for 5 or 6 miles above its mouth has no flood plain and but few tributaries. At Bluff, Meadow Fork enters it from a valley that for some miles is likewise narrow and rough, but that widens farther up and contains some excellent bottom lands. These bottom lands have not been injured by floods, for the surrounding mountain slopes are very largely forested, only about 20 per cent being cleared, and most of this is in grass and pasture. It shows, as a rule, no signs of washing. The valley of Spring Creek itself, above the mouth of Meadow Fork, is narrow for several miles, but broadens at Spring Creek post office and contains some of the very best lands in Madison County. These lands have not been injured by overflow. Farther upstream bottoms exist only in isolated patches or narrow strips and are relatively unimportant. Probably 80 per cent or more of the steep mountain slopes in the upper part of the basin are in timber, but most of the merchantable trees have been cut in the last 15 or 20 years.

Big Pine Creek is very rough along most of its course, the valley walls being close to the stream and rather steep. They are, however, very productive where cleared, but are inclined to wash except when kept in grass, as most of them have been. Only a relatively small proportion, perhaps 15 or 25 per cent, of the valley slopes have been cleared.

Little Pine Creek shows about the same conditions as Big Pine. There is a narrow flood plain here and there, and the lower slopes have been cleared in slightly greater proportion. The stream has done no notable damage to lands along its course.

Sandymush Creek has no bottoms for 4 or 5 miles from its mouth; farther upstream some small separate flood-plain areas occur, but there are no important bottom lands below the forks. On Little Sandymush the bottoms are good but narrow, but on Big Sandymush they are considerably broader and more valuable. The hillsides have been cleared in larger proportion than on the streams already mentioned, the cleared area averaging perhaps 40 to 50 per cent. These cleared lands contain a smaller proportion of sodded area than is usual, and as a consequence they show many more signs of serious erosion, and it is not surprising that the bottoms along both Little and Big Sandymush had in some places been greatly damaged by floods. Below the junction of the two streams several mills, as well as the soil on many small flood-plain areas, had been swept away. From this difference in these neighboring streams it would appear that under such climatic and other conditions as are found in these mountains the danger line between a safe and an excessive amount of clearing would lie somewhere between 20 and 40 per cent. It would, of course, vary considerably with local conditions of soil texture and slope. If this conclusion is correct, then the French Broad basin, as a whole, is already cleared to an excessive extent.

From Marshall to Leonard and the mouth of Big Laurel Creek the road is on the old plateau surface, here steeply rounded by many sharply incised streams. The land has been cleared to a varying extent, depending on the nature of the soil and the geology. Where the rocks are granitic the soil is deeper and better and 75 to 80 per cent of the area is cleared; where the rocks are slates or quartzites the soil is thinner and much poorer and only 10 to 20 per cent is cleared. The granitic areas show considerable hillside erosion, and the small streams are being choked with débris, so that in many places the narrow strips of bottom lands along them have been ruined. In the slate areas the streams show no signs of aggradation but are actively cutting away the rock along their courses.

Big Laurel Creek has no flood plain for a number of miles up from its mouth, and its valley sides are steep and rocky and practically uncleared. Little and Big Hurricane creeks flow from quartzite and slate areas, in wild, rough, narrow gorges, with no flood plains worthy of mention, and their basins show very few hillside clearings. Little Laurel Creek is bordered here and there by a few acres of poor, sandy bottoms which do not show material damage from floods. The lower slopes are in some places cleared for short distances up the mountain side and many such areas are kept in grass. The higher slopes are practically uncleared, and much of the basin is rough and wild. Shelton Laurel Creek has somewhat more bottom land than Little Laurel, and about 20 per cent of the lower mountain slopes are cleared; the higher slopes are largely in forest. The amount of damage by floods has been inconsiderable. There are no mills, dams, or bridges to be washed away, and only exceptionally have the lands been much eroded. All the tributaries of Big Laurel, as well as Big Laurel itself, flow most of the time with clear currents and are as a rule bordered by little or no flood plain.

From the mouth of Shelton Laurel Creek to the mouth of Spillcorn the hills rise to the old plateau level, are deeply incised by many small streams, and are steeply rounded. The land, however, is very fertile and 75 to 80 per cent of it is cleared. Some of it is in grass, but much of it resists erosion to a remarkable extent even when kept in clean culture, owing undoubtedly to the porosity of the soil, which is the result of the weathering of a coarse porphyritic granite. Along Big Laurel itself in this stretch there are no bottoms for a number of miles. In some places 20 to 25 per cent of its lower valley sides have been cleared, in others they are practically untouched.

The basin of Spillcorn Creek contains very little bottom land. Almost all of the cleared land is on the lower slopes of the mountain sides, some 25 per cent of which has been cleared. Much of this cleared land has been under cultivation for a number of years, and probably a fourth of it has been practically ruined by gullying within the last few years. No mills or dams have been destroyed along the stream.

From Big Laurel post office, near the mouth of Spillcorn Creek, to Little Creek post office, the occasional flood plain areas are more or less sandy and stony and show some tendency to undercutting by shifting of the stream channel during floods. Above Little Creek post office the valley is somewhat broader and the flood plain more continuous and better. A considerable area on both valley walls has been cleared. That on the northern side is old and worn with gullies; that on the south side is fresh and as yet uneroded. More of the cleared area is in grass than farther downstream. The bottom lands along Little Creek show some signs of stream aggradation, so that the drainage is not so good as it should be, and it is said to be slowly becoming worse.

An old resident of the region, a highly intelligent and close observer, believes firmly that there have been marked changes in the regimen of the Big Laurel in the last 25 years, during which time most of the lumbering and clearing has been under way. The floods in former days rose more slowly, reached lower heights, endangered property less, and went down more slowly, so that it was no unusual thing for the stream to remain up during flood periods for several days. Within recent years, however, floods have come abruptly, rising within a few hours to heights previously unknown, sweeping away everything in reach, and subsiding almost as rapidly as they rose. Many springs that were formerly perennial now go dry or practically dry late in summer. During this season the small grist mills along the stream are unable to grind the grain, and steam mills must soon be built to replace them. Houses that several decades ago were high and dry above the greatest known floods have in recent years been repeatedly surrounded by water. There can be little doubt therefore of the truth of the contention that there has been a change of stream regimen. This material change in the character of the stream, especially in its flood flow, has been a result of the lumbering and subsequent clearing away of the forest, which have caused the more thorough drying out of the soil and the more rapid surface run-off of the rainfall.

About Windy and Ivy gaps there are numerous old mountain-side clearings that have been eroded and abandoned and are now practically covered with second growth. South of Ivy Gap the valley of Little Ivy River abruptly broadens until it is several miles wide. For the most part it is made up of rounded hills, 100 to 200 feet high, whose tops form part of the old Asheville Plateau level. The flood plain itself is narrow at the head of the river but gradually broadens until it averages 100 to 300 yards in width in the middle and lower parts. The stream is broad and shallow and flows over sand and cobbles, and in many places the water level is very little below the flood plain surface. Parts of the flood plain can be drained with difficulty and in recent years have been converted into a somewhat swampy meadow of no great value. This stream is unable to remove the eroded material furnished it and is aggrading and ruining its flood plain.

The history of changes in the basin of Little Ivy River during the last twenty years is exceedingly interesting, and typifies the general tendency of changes in all mountain basins that have been extensively cleared. Some 15 or 20 years ago a certain grade of tobacco was found to grow well on the gneiss soils of the region, and its culture was so profitable that in a few years the low rounded hill lands and the lower slopes of the higher mountains about the edge of the basin had been largely cleared and planted in tobacco. The cultivation of tobacco was continued year after year until a decrease in the price, together with a decrease in the yield through the depletion of the humus in the soil, finally caused it to be abandoned. As soon as the humus had been destroyed the hills began eroding badly, and to-day the old red-gullied fields and an occasional tobacco barn are the only evidences of this agricultural episode visible on the hills themselves. Other evidences are, however, visible on the bottom lands. My

informant stated that when he was a boy, some 40 years ago, the stream channel was bordered by high banks, contained but little sand, and in may places its bottom was rock. The water was clear and contained abundant trout and other fish. Deep pools, he said, were numerous, and he pointed out the location of several that were memorable as boyhood swimming and fishing holes. The bottom lands near his residence were never known by his father, or by himself in his early years, to be covered by floods; floods resulted only from several days of continued rains, and even when at their highest the water was measurably clear, the discoloration being of grayish cast. A mill erected 30 years ago, had the dam so arranged that half of the water was turned into the race and went to turn the wheel. Since then no change has been made in the height of the dam, in the wheel, or in the gearing, nor has any additional machinery been put in; the power demands, in other words, have not been changed. Note, however, the other changes. Since the rapid clearing incident to the introduction of tobacco culture in the basin, sand is everywhere. The deep channel has been filled with it, so that the water level is now close to the flood-plain level, and a slight rise suffices to raise the stream over its banks. Floods are frequent, and the growing of crops has become uncertain, even where the land itself has not been destroyed by being washed away or covered with sand. A heavy rain of a few hours now produces a flood that rises rapidly and as quickly subsides; the water becomes red with mud and remains so for several days after it has fallen to normal height. The sand and the mud have filled the swimming holes and driven away the trout and bass; a mud cat or sun perch is the only fish now to be found. The bottoms, formerly never covered by high water, were flooded for the first time six or eight years ago, and have been covered several times since then. The low-water flow of the stream is so much less than of old that all of it is now turned into the mill race, and yet there is more difficulty in grinding with the entire stream flow than there formerly was with but half of it. Springs that in former years were never known to fail now go dry in summer and remain dry for several months.

Paint Fork and California Fork have similar topography and soils and have had the same agricultural history, followed by the same disastrous results as those just described in detail for Little Ivy River.

Holcomb Branch and Poverty Branch have small basins with narrow flood plains and steep slopes, both of which have been much eroded and abandoned. A few days before Holcomb Creek was examined the worst flood in its history occurred; it swept away the growing corn, the shocks of oats, and the fences, and in many places washed off the soil to the bare rocks and tore up the road. The flood was scarcely less severe on Poverty Branch.

At Democrat a milldam pond on Ivy River has so filled with sand and clay that it has no storage capacity, and the low-water flow permits but very little grinding in late summer and fall. The miller claims the stream volume is less than half of what it was some years ago during this season. There are no bottoms worthy of mention along this portion of the river.

The miller at Barnardsville says that in autumn he now has only about half the water that he had some years ago and is in that season forced to shut down a part of his machinery. Above Barnardsville much of the valley land forms part of the old Asheville Plateau surface; about 50 per cent is cleared. The mountain slopes proper are probably not more than 15 per cent cleared.

On the day before it was examined Martins Creek, a small stream flowing into North Ivy at Barnardsville, had a flood that was described as coming downstream with an almost precipitous front and subsiding almost as suddenly as it came. Although the basin is insignificant in size, the incident is important as showing the character of the floods that have become so destructive in these mountains.

From Barnardsville southward to Reems Creek the uplands have been cleared to a considerable extent, but in many places have been kept in grass. Along Reems Creek and Ox Creek the slopes have been largely cleared, and where they have not been properly cared for show much erosion. These streams are small and rather torrential and in places are undercutting their bottom lands or have washed runways across them. The higher slopes of the mountains to the

east are largely uncleared. Portions of the crest of the Elk Mountains are cleared and in excellent grass, as the soil is fertile.

FROM HOT SPRINGS THROUGH THE MOUNTAIN.

Below Hot Springs the French Broad flows for 20 miles in its mountain gorge. Its current is very swift and its channel in places contains abundant cobbles and bowlders. Here and there it is bordered by small flood plain areas, most of them on the concave side of a meander curve, which, as a rule, are sloping, are somewhat stony, and have a sandy soil that is rarely fertile. Around the curves the bottom lands have been gouged into holes or in places have washed away. The total amount of injury done in this gorge portion of the stream, however, is inconsiderable, because of the small amount of flood plain that could be destroyed. The mountain slopes are generally very steep and many of them are rough and rocky. They are practically uncleared, though nearly all of the timber on them has already been cut.

GREAT VALLEY PORTION OF THE FRENCH BROAD BASIN.

GENERAL CONDITIONS.

For a few miles below the point at which the river leaves the mountain it has no flood plain, but about 4 miles above the mouth of Big Pigeon River a broad flood plain begins and extends thence to the mouth of the river—75 or 80 miles—on one side or both. Its width ranges from a half mile to a mile or even more. It is composed of fine sands and clays that almost invariably make fertile soil. None of these bottom lands are worth less than $60 and many of them bring $100 or more an acre. In many places the yield per acre is 80 to 100 bushels of corn.

From Leadvale down to its mouth—a distance of 70 miles—the river is navigable. The bottom lands on the concave side of the bend at Leadvale had been damaged to the extent of $3,000, and the railway pier on the same side had been partly undermined by the floods of 1901 and 1902. Morris Island, below Leadvale, was not greatly damaged, but on the bend immediately below it there was much washing, and at Allens Ford an 8-acre island was washed completely away, and the western bank of the river was badly scoured. Much of the surface soil of the farm in the bend just south of Allens Ford had been swept away by the current. In general it may be said that on this river, as on the Holston and the Nolichucky, farms within bends are more injured than those elsewhere. Many of them have been scoured down to the hard clay or the bare rock. At Oak Grove two or three farmers reported damages ranging from $500 to $1,000, and conditions at this point are typical for this portion of the river.

Between Oak Grove and Elliott Ferry the bottom lands lie on the west side of the river. They are about three-fourths of a mile wide and are protected in a large measure by a levee built across their upper end. Their surface ranges from 12 to 20 feet above stream level and only the lower parts of it are covered by floods. These parts have been slightly injured in recent years, but the damage has been much less than the average in other places.

From Elliott Ferry down practically to Dandridge the flood plain has an average width of three-fourths of a mile and is confined almost entirely to the north side of the river. At the ferry there is on the north side an ordinary flood plain 10 to 20 yards wide and 6 feet above ordinary water level. It is bordered by an extraordinary flood plain some 10 to 15 feet higher and 250 yards wide. From the ferry to Dandridge the flood plain has been injured not so much by the river current as by the cutting of channels during the return of the flood waters to the river as it falls. These channels are transverse to the main river channel and have scarred the flood plain in many places.

Swan Island, with an area of 150 acres, has had 30 or 40 acres of its upper end scoured off down to hard clay; its lower end, however, has been benefited by a deposit of fertile silt. Another small island near by, comprising 22 acres, had all of its top soil washed away.

At Dandridge a farm on the south side, just above the ferry, was in an eddy and was considerably benefited; the soil on a farm on the same side just below the ferry was washed away

to hard clay. McManns Islands appear to have been benefited by deposition of silt. These islands, however, deflected the currents, so that the bottom lands west of them and below them were badly injured. In the first farm below on the south side of the river numerous holes, 6 to 10 feet deep, were cut; the next farm below was covered with sand 4 to 5 feet deep and rendered practically worthless. Other farms in Jefferson County have been damaged, chiefly by the cutting of holes and the washing of the surface, to an average of about 10 or 15 per cent of their value. In some places later floods have deposited sediment where earlier ones had washed, so that some lands show improvement and may be reclaimed in a few years; in other places the damage seems permanent and there are no signs of the land making back again after three or four years of disuse.

In general, the areas covered by white sand become fewer toward the lower end of Jefferson County, but near the mouth of Little Pigeon River, in Sevier County, the damage from the covering with white sand becomes greater. It is evident that the Pigeon delivers a larger amount of such material than the French Broad can remove and the latter is consequently forced to deposit its excess of load within a short distance below the mouth of the Pigeon. Throughout this portion of the French Broad there are many changes in the channel, some of which have interfered with the ferries, and many channels back of islands have either materially filled or scoured in the last few years. Places that are shallow after one flood are scoured out deep by another, and vice versa. At Huffaker Island the north channel has practically filled. At Pickle Island, just below, the south channel has in like manner filled.

The height of the flood determines whether deposition or scouring shall occur in a given place, and as the flood height varies from time to time the frequent changes in the depth of the river may be easily explained. River men and boatmen claim that the channel, as a whole, shows a tendency to fill. It is believed that the average depth of the stream is not so great as it formerly was, and it is confidently asserted that boats can not run as far upstream in summer and fall or as constantly as they could in former years.

The changes in depth and the tendency to fill, because of the great and increasing volume of sand now being carried down the river, repeatedly make difficulties for steamboats and largely nullify the efforts of the Army engineers to maintain a navigable channel. Sand bars dredged to-day may be re-formed to-morrow, and as long as the sand and cobbles are permitted to get into the stream no permanent improvement is possible. Dredging must be continued.

PIGEON RIVER BASIN.

Pigeon River rises among the Balsam and Pisgah Mountains, cuts its way through the Unaka Mountains, and joins French Broad River on the Tennessee plain. It drains an interior agricultural basin which is oval in outline, the longer axis extending northwest-southeast, parallel to the general course of the stream, and almost entirely within the Appalachian Mountain region. It is circumscribed by lofty mountains, many of the peaks reaching altitudes above 6,000 feet. Many minor ranges springing from the surrounding mountains converge toward the middle of the basin, dividing it into deep, narrow valleys, except near its upper end, between the towns of Canton and Waynesville, where there is a broad, open valley of alluvial plains and rolling hills, dotted with low mountains.

The basin has an area of about 667 square miles.

The soils are loams and sandy loams, mostly fine grained, derived from gneiss and schists, though in the mountains they are more siliceous and coarser, being the product of metamorphosed sandstones, quartzites, and conglomerates.

Waynesville is situated on a part of the old Asheville plateau that has been dissected by the river and its tributaries in the same manner as the region about Asheville has been dissected. The soils are eroding much as they are elsewhere on this old plateau.

From Waynesville eastward to Davis Gap much of the country is cleared. The surface is rolling to hilly and eroded areas occur here and there. In the gap itself, especially on the north side, the lands have been badly gullied. East of the gap, toward Sonoma, about 85 per

cent of the lower and 30 per cent of the higher slopes are cleared. Some clearings extend well to the tops of the ridges.

At Sonoma a prominent terrace lies 25 feet above the broad semitorrential flood plain. Viewed broadly, this terrace appears level, but viewed in detail it presents minute undulations caused by numerous obscure runways and small hummocks over its surface. It is rather fertile, as such torrential flood plains usually are, and is now fossil.

Above Sonoma, nearly up to Lavinia, the West Fork of Pigeon River has considerable flood plain, practically all of which is cleared. A large proportion of the lower mountain slopes is also under cultivation, much of it being in grass. From Lavinia up to Three Forks the narrow flood plain and the lower 100 to 200 yards of the valley sides have largely been cleared. In places the older of these mountain-side fields are badly eroded.

Above Three Forks the basin of the Pigeon is practically uncleared and is largely in original forest, untouched as yet by the lumberman.

On Little East Fork there are few flood-plain areas, as the valley is narrow and the stream torrential, but the valley sides are cleared to a greater extent than on the West Fork. These lands are more fertile and are largely kept in grass, so that their condition is usually good.

Along the East Fork a large part of the flood plain is torrential, a poor, sandy soil, 2 to 3 feet deep, overlying a cobble stratum. It is crossed by flood channels and cut by holes, especially where it is forested. The scouring out of holes during floods is commonly caused by the lodging of logs and the formation of rafts. Such obstructions are especially likely to form on forested plains and the water deflected beneath them exerts great scouring force and quickly removes all loose material down to the underlying rock. For some distance up East Fork the mountain sides are practically uncleared, but at and above Springdale considerable areas of fertile land are being cleared and put into apple orchards. Grass is usually grown on the same land until the trees come into bearing. A very large part of this basin, however, consists of the steep slopes of the Pisgah Mountains, whose peaks include many that stand more than 5,000 feet and several more than 6,000 feet above sea level.

From Sonoma down to Canton the flood plain is broad and fertile and the larger part of it is cleared and cultivated. Many remnants of a well-developed fossil flood plain rise by a steep scarp about 25 feet above the living flood plain. The stream is doing comparatively little damage to the lands along it. Perhaps 50 per cent of the mountain slopes on each side are cleared and on some of them fields reach to the tops.

At Canton a large pulp mill, having a capacity of 500 cords of wood a day, has been erected. Much of the wood comes from the upper Pigeon basin, but a considerable part is shipped in by the Southern Railway.

From Canton westward to Clyde the river has not seriously damaged its bottom lands, which are, in general, sandy and lie less than 10 feet above ordinary water level. The rapid current of the river prevents floods from reaching even this height, though they are said to have become higher in recent years than they were formerly. The removal of the timber in the upper basin will probably cause floods to become steadily worse.

From Clyde to Waynesville the uplands are hilly and have a deeply rotted gneissose soil that in many places has been cultivated for years and has become badly gullied. A few miles below Clyde, Pigeon River valley closes in and has very little flood plain down to the mouth of Jonathan Creek, but a large proportion of its valley slopes are cleared. Many of these cleared slopes are kept in grass and are uninjured by erosion, though some of the older fields, not so protected, have eroded badly.

Below the mouth of Jonathan Creek the river cuts for 25 miles through the Great Smoky Mountains in a steep-sided gorge whose walls rise 2,000 to 3,000 feet above stream level, are generally rough and rocky and in many places precipitous and are uncleared. There is no flood plain in this part of the river.

After the river leaves the mountains its flood plain for 10 miles is narrow and has been badly washed or has been covered by sand. A few miles above its mouth its valley broadens, its slope decreases, and it has developed a wide flood plain, chiefly of sand and therefore only

moderately fertile. The floods of the last few years have injured it about 15 per cent and in places have washed away the railway embankments.

On the north side of the Pigeon, below Canton, the sides of the basins of Crabtree, Fines, and several smaller tributaries include many areas of fertile land, a large part of which has been cleared. Much of it is kept in grass and is generally in good condition. The flood-plain lands along these streams are narrow but have not been materially injured by floods.

Soco Gap, at the head of Jonathan Creek, is a small cleared area which is well grassed and thus completely protected from erosion. The upper part of the basin for 2 miles below the gap is in forest that has recently been lumbered and is now cut by numerous runways made by the lumbermen. Below this lumbered area the entire narrow flood plain has been cleared and is partly in grass and partly cultivated. It is a torrent plain, 2 to 15 feet above stream level, and ranges in width from 200 to 600 yards. The rounded stones on its surface are prominent in the portion above Tito, though its soil is fairly fertile. Fertility is, indeed, a common characteristic of such torrent plains, but whether because or in spite of the stony débris is not always apparent. If in spite of, the source of the fertility is to be sought in the large amount of humus usually present in cove soils, much of which would readily be washed down the steep slopes and incorporated in the torrent plain; if the stony débris aids fertility, it must be because it helps to keep the soil more open and loose by preventing baking during the drought and by retarding evaporation.

The stream itself is rough and swift and its bed is made up of a succession of small bowlders and gravel bars. In many places it is bordered by a cobble zone 50 to 100 yards wide, and over this cobble zone the stream constantly shifts its position. Log and rock cribs have been built to restrain and confine it.

The valley walls on each side rise steeply and are cleared in an irregular manner; in some places both sides are in timber; in others clearings extend up the mountain side 300 to 600 feet above stream level; on the west side there is a large cleared area on the higher slopes. Most of the cleared land is in grass and in good condition; perhaps 10 per cent of the remainder shows gullying, though much of that not gullied has been cleared within the last few years. At Tito the creek turns sharply northward from its old course to the Pigeon and flows for a mile or more in a narrow gorge, below which its lower valley opens and broad bottoms appear. These bottoms are generally in good condition. The valley wall on the east side shows occasional clearings on the high mountain slopes, but no erosion was seen.

Along Hemphill Creek, on the west, the small flood plain is cleared, and also some 60 per cent of its valley walls up to an elevation of 600 feet above its channel; on the north side there are many fields up to the tops of Purchase and High knobs, nearly 3,000 feet above the stream. When newly cleared these are in good condition, but some of the old clearings are badly gullied.

Below Hemphill Creek the flood plain on Jonathan Creek is broad and in good condition. It is bordered by a terrace whose surface stands about 75 feet above the stream and is almost entirely cleared. Areas comprising about 20 per cent of the low valley slopes are also cleared and are largely in grass. Below the mouth of Cove Creek there is no flood plain.

In Cove Creek valley all of the bottom lands and 60 per cent of the valley walls, for 300 to 400 feet vertically, have been cleared. About 10 per cent of the cleared land is in old fields that show erosion.

West of Camp Gap the entire country from the Balsam Mountain across to Pigeon River and from Camp Gap to the Great Smokies on the Tennessee line is almost entirely uncleared; the clearings would include perhaps 2 per cent of the area. Some of the lands in these clearings are fresh and part of them are in grass. On most of them the soil is loose and porous, containing as a rule many small rocky fragments, so that even the few fields that have long been cleared show much less erosion than might seem probable from the steepness of the slopes.

At the time of the examination both Cataluchee and Big creeks were much swollen by several days' rain. Cataluchee Creek was almost clear and Big Creek was quite so. The explanation of their clearness lay in the almost completely forested condition of their basins,

which therefore furnished no eroded mineral soil particles to their flood waters. A lumbering railway has recently been built from Newport up the Pigeon and up the valley of Big Creek. The lumbering operations will probably produce important changes in the stream's regimen, and the results so familiar in other basins where forests have been extensively cut will be repeated here.

From the State line westward across the headwaters of Cosby Creek and Webb Creek to Little Pigeon River much of the road is on an old, well-dissected plateau, which in the great valley of east Tennessee is regarded as the equivalent of the Asheville Plateau, though it lies at a somewhat lower elevation. West of the Great Smoky Mountain this old plateau is from 1,900 to 2,100 feet above sea level and is remarkably well preserved in its broad features, though cut to pieces in minute detail. Isolated peaks or short ridges rise steeply above it, and innumerable streams and streamlets have cut sharply beneath it. In many places a large part of its surface is cleared. The slopes downward to the streams are cleared in like or greater proportion. The slopes upward on the mountain sides have been practically untouched by the farmer, though the lumberman is actively at work and in many places has already removed the best timber.

The creek bottoms vary in width from 100 to 300 yards. As a rule a narrow cobble zone borders the stream channel, but the general condition of the bottom lands is good. There has been no marked increase in erosion recently. In many places the streams flow over the upturned edges of Paleozoic rocks and are actively eroding their channels. Their bounding mountain slopes are forested and furnish to the streams very little sand and gravel.

At the mouth of Webb Creek Little Pigeon River flows with a very swift and perfectly clear current over ledges of upturned slate or bars of cobbles and bowlders. In some places its valley sides close in so narrowly that the river is bordered only by a cobble zone; in others they recede and there is a fertile flood plain 300 to 400 yards in width and 10 to 15 feet in average height above stream level. On the higher parts of the flood plain houses, barns, and churches have been built. From the mouth of Webb Creek well up to the head of the stream the bottoms are cleared and much of the lower mountain slopes are also in cultivation.

Though floods on Little Pigeon seldom do serious damage, they are generally thought to be growing worse. The stream is slowly cutting away its flood-plain and widening its bowlder zone; fences and roads on the edge of the flood plain next the stream have had to be moved back repeatedly. The flood plain appears to have been a fossil one, but within recent years seven houses, two barns, and a schoolhouse, as well as much fencing and roadway, have been swept away by high waters. It may, however, have been an extraordinary flood plain, reached by floods only at long intervals; or it may have been a plain abandoned by floods because of the constantly deepened stream cutting under natural forested conditions, now reoccupied by floods whose height has been abnormally increased by man's activities.

Between Middle Fork and Gatlinburg the flood plain of Dudley Creek is entirely cleared and is in good condition. The bounding valley slopes up to a height of 100 to 200 feet above the stream are 60 per cent cleared, and there is at rare intervals a cleared field on higher slopes. The high mountains here, as practically everywhere else on this west slope of the Great Smokies, are uncleared.

At Gatlinburg the conditions are about the same as on Middle Fork. The destruction by floods is growing, the zone of bowlders bordering the stream channel is slowly widening, and roads, fences, and small houses have to be moved back from the crumbling edge of the flood plain.

Alum Cave Creek is a typical clear mountain torrent, with a descent of 200 to 400 feet per mile in a channel that in places is cut 30 to 40 feet below an exceedingly rocky or bowldery but fertile torrent plain. The channel is filled in many places with bowlders, the largest 10 or 15 feet in diameter. On the steep mountain side there are a few clearings whose soil is usually stony but has not eroded appreciably. The higher valley slopes are timbered and from a point about 6 miles above Gatlinburg to the crest of the Great Smokies at Indian Gap there are no

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houses or clearings and the forest is primeval, untouched by the ax. The region east of the gap belongs to the drainage system of the Little Tennessee.

LITTLE RIVER BASIN.

Little River heads on the west slope of the Great Smokies, flows northwestward, and enters Tennessee River 12 miles below Knoxville. Its basin lies between the basin of the French Broad and that of the Little Tennessee and is divided by the Chilhowee Mountains into a lower northwestern part, in the great valley of east Tennessee, and an upper southeastern part, inclosed by the Great Smokies and their spurs.

The lower or valley part of the river is bordered by a narrow flood plain that is in most places fertile and is in generally good condition as regards erosion. The upper, mountainous part of the stream has as a rule no important flood plain, although here and there a narrow, rather sandy strip of bottom land occurs, and at one place the erosion of a small area of limestone infolded among the ancient schists of the region has produced a beautiful broad valley known by its Cherokee Indian name of Tuckaleeche Cove. The land in this cove is very fertile and is practically uninjured by floods. In it a lumber company has in recent years erected a large sawmill, around which has sprung up a considerable town. From the town a logging railway follows the river up practically to its head, at the very base of the Great Smokies. Above Tuckaleeche Cove there is practically no flood plain and almost no mountain-slope farm clearing, so that until lumbering began the region was an unbroken forest. The timber is now being rapidly removed. The cutting is close and leaves the land almost bare.

Much of the area is steep, rough, and stony, and not suitable for agriculture. It needs protection from fire and should have careful attention until the forest cover is reproduced.

LITTLE TENNESSEE RIVER BASIN.

GENERAL FEATURES.

The headwater tributaries of the Little Tennessee rise along the Blue Ridge in North Carolina or northeastern Georgia, and the main stream flows northwestward across the mountain region to its junction with Tennessee River in the middle of the great valley of east Tennessee. The basin lies southwest of the basin of the French Broad and northeast of that of the Hiwassee, and is 85 miles long, from southeast to northwest, and 40 miles wide. It is more nearly inclosed by high mountains than is the French Broad Basin. Many peaks on the Blue Ridge along its southeastern rim rise sharply to heights of 4,000 to 5,000 feet above sea level. Along its northeastern side the bounding rim is a nearly continuous chain that in numerous places is between 5,500 and 6,500 feet high. The Great Smokies, on the northwest, reach elevations of 3,500 to 6,000 feet, and though the bounding ridge on the southwest is somewhat more broken, yet parts of it are more than 5,000 feet high.

The immediate river valley is broad and has gentle slopes where the rocks are less resistant to weathering, but is narrow, steep walled, and in many places rocky where they are more resistant. In common with the other westward-flowing streams in this region, the depth of the gorge increases downstream, being 1,500 to 2,000 feet deep where the river breaks through the Great Smokies on the Tennessee line. The open, flat-floored basin-like character of the Little Tennessee Valley is much less perfect than that of the French Broad, its interior being broken by numerous high ranges, some of which extend for several miles and reach elevations of 4,000 or 5,000 feet above sea level. The Cowee Mountains, for instance, are 30 miles long and reach heights of more than 5,000 feet. The Plott, Balsam, and Hughes Ridges, though less than 12 miles long, rise to elevations between 5,000 and 6,000 feet and culminate where the Plott Balsam joins the main Balsam, at an elevation of 6,399 feet. Other ridges, such as Cheoah and Nantahala mountains, are of almost equal extent and height.

The old plateau surface which forms the floor of the basin is identical in age with and similar to the Asheville Plateau and is well preserved about Webster, above and below Franklin, and in the Cheoah basin about Robbinsville. These places are situated on its level.

TUCKASEGEE BASIN.

BALSAM GAP.

West of Balsam Gap 40 per cent of the steeply rounded hills at the head of Scott Creek have been cleared. Many of these cleared areas have been cultivated for years and have become deeply gullied. A large number of such gullied fields have been abandoned, and in numerous places nature has not yet succeeded in repairing the damages wrought by man, so that the bare red clay surface on these scarred hillsides is becoming constantly larger, and new fields are being cleared whose ultimate fate will be the same as that of these eroded areas.

This region vies with the Burnsville and Bakersville regions in the amount of damage caused by erosion on the steep uplands, but, luckily, conditions elsewhere in the Little Tennessee basin are not so bad as in the part of it just west of Balsam Gap, although badly eroded areas are by no means unknown or even infrequent in many other parts of the basin.

Down Scott Creek many hilltops and hillsides have long been cleared and show serious gulleying and sheet-wash erosion. The small streamlets flow in narrow, sharply incised valleys.

On Scott Creek from Hall down to Dillsboro areas of bottom lands from 100 to 400 yards wide occur here and there in bends of the river. Many of the steep valley slopes are partly cleared and cultivated, and almost every field has been badly eroded before the deadened trees that were left standing when the land was first cleared have disappeared. The old fields are abandoned. This policy of clearing, temporary cultivation, and abandonment is, indeed, general; and in many places throughout the mountain region the succession from forest to freshly cleared fields, old fields, and abandoned badly eroded fields may be seen on adjoining parts of the same mountain side.

At Webster, as indeed through most of its course above Dillsboro, the Tuckasegee is deeply incised beneath the old plateau level and is bordered by little bottom land. A county road follows it throughout almost its entire course, and within recent years the many high floods have torn to pieces long stretches of this road and have swept away a number of bridges.

Just below Dillsboro the river has little or no flood plain. For a short distance it flows in a narrow gorge and has a considerable fall, and this section has recently been purchased for use as a power site. Between Wilmot and Whittier there are good bottoms 100 to 300 yards wide showing comparatively little injury from floods. In some places sand has been washed over them to a slight extent. The uplands on the north side of the river are cleared but not to the extent that they are above Dillsboro. The slopes here are gentler and the surface is not washing so badly.

Below the mouth of Oconalufty River the bottom land is made up of poor, micaceous sand, and additional deposits of such sand are being brought down from the Oconalufty, evidently from the basin of Soco Creek, since that is the only tributary of the Oconalufty in whose basin conditions as regards erosion are bad.

Just above and at Bryson City the flood plain is 300 to 400 yards wide, and most of it is either an extraordinary or a fossil flood plain, usually or always safe from flood damage. From Bryson to Bushnell the river flows in a narrow, rocky trench in which there is practically no flood plain, and the sides are too steep and rocky to be cleared and cultivated. Above this trench the uplands back on the plateau level are 30 to 40 per cent cleared. The soil is gravelly to sandy, is porous, and shows very little erosion. The steep slopes of the higher mountains are not cleared.

At Bushnell, where the Tuckasegee joins the Little Tennessee, there are no flood plains worthy of note, but some houses are being built within the reach of extraordinary floods. The highest flood reported at Bushnell occurred in 1867, and it is said that one in 1840 was nearly as high. Since 1867 there have been several floods that have reached within 3 to 4 feet of the 1867 stage. In recent years several bridges and a mill or two in the vicinity have been destroyed by high water, and in 1900 some 2,000,000 feet of logs were swept away by the breaking of a lumber company's boom, and the company went bankrupt.

OCONALUFTY RIVER.

Oconalufty River is tributary to the Tuckasegee on its north side, and its basin contains much of the highest, widest, and most densely forested land to be found in western North Carolina. It is bounded on the north by the Great Smokies and the Balsams, which rise to a height of more than 6,000 feet. The larger part of the basin is occupied by the Qualla Reservation of the Cherokee Indians, and this fact accounts for the large proportion of uncleared land within it. The Indians usually do but little farming, and the clearings are confined to the better bottom lands and the lower valley slopes, many of which are rented and farmed by whites.

From Indian Gap for several miles down the headwaters of Mingus Mill Creek the region is in virgin forest that at the time of the examination was just beginning to be lumbered on an extensive scale. Thousands of feet of the finest poplar and other hard woods had been felled and cut into saw lengths but had not been moved to the mill. A tramway down the valley was being built to carry the lumber to the railway. Some 4 or 5 miles from the head the narrow flood plain begins to be cleared, and from there to the mouth, at Oconalufty, it is almost continuous and averages somewhat less than 200 yards in width. Some parts of it are flat, but most of it is a beveled plain and is above the reach of floods. The valley walls are cleared to a slight extent only, and then merely for a short distance above stream level. The higher slopes are in unbroken forest.

Below the mouth of Mingus Mill Creek Oconalufty River has a bottom 200 to 500 yards in width that is, as a rule, fertile and is uninjured by floods; the upper portion of the Oconalufty is in practically the same condition as to clearing and flood damages. The forested slopes have everywhere protected the bottoms from serious injury.

Soco Creek, also in the Cherokee Indian Reservation, has moderate fall and a flood plain that, though here and there quite narrow, averages 200 to 400 yards in width. This flood plain is in some places normal, having a flat surface and rising 4 to 6 feet above stream level; in other places the stream is receiving more waste than it can carry away and is aggrading its flood plain, so that the part next to the channel is higher than that more remote from it. The flood-plain surface is accordingly convex, and, during floods, distributary channels are frequently cut from the main stream to lower parts of the flood plain nearer the valley wall. Here and there these channels are occupied by the stream, which consequently widely shifts its position. The surface is being scored by such channels, and islands are frequently formed and as frequently tied to one side or the other of the flood plain by the abandonment of one of the channels around them. The material deposited by the stream is for the most part coarse and stony, and the hill slopes are moderately steep, and only some 25 per cent of them up to an elevation of about 200 feet above stream level is cleared. Part of the cleared area has been worn thin and abandoned, but does not show profound gullying. The higher slopes are entirely forested. The soil has resulted from the weathering of granites and gneisses and is somewhat stony and porous. It is much like that on the Oconalufty, and yet there is a notable contrast in the flood-plain conditions on the two streams. On the Oconalufty the flood plain is generally in good condition; on the Soco much has already been ruined, and the remainder will soon be in like condition. An explanation of this difference is found in the fact that from about 1896 to 1898 the Soco basin was thoroughly lumbered and many runways were opened down the steep slopes, and these have furnished the coarse material that has since overloaded the stream and is now accumulating on its flood plain, burying and ruining the alluvial soil.

From Hall station southward to Painter, on the Tuckasegee, many old fields have been eroded and abandoned. Where these have not been turned into pasture lands they have generally grown up in timber and the erosion scars have in time been covered by vegetation, though in many places the surface is left too rough for subsequent clearing. They are, however, more frequently fenced in for pasture, and, when grazed and trampled, erosion conditions grow constantly worse until many of the fields become areas of bare red clay. Throughout this region the best timber has been culled and hauled by wagon to the railway.

Cove Creek has a narrow flood plain and 25 to 40 per cent of its slopes are cleared; the older fields are eroding.

Weary Hut Creek has almost no flood plain and its valley sides are not greatly cleared.

Caney Fork is in places bordered by some good bottom lands, but its current is relatively swift, and though many of the lower slopes have been cleared, all of the higher ones are in forest. Conditions throughout the basin as regards erosion are generally satisfactory. In recent years, however, some damage has been done to the flood plain on the lower course of the stream.

Floods on the Tuckasegee are said by old residents, some of whom have known the river for 60 years, to be generally higher, to come more suddenly, to disappear quicker, and to be much more destructive than 50 years ago. Both the river and its tributaries are said to be much muddier during floods and for a considerable time afterwards than they formerly were. and many springs that were once perennial now go dry in late summer. During the fall the river and the smaller streams tributary to it get lower than of old, and mills have more difficulty in running. It is thought that the increased height of floods and irregularity of flow are the result of clearing for agriculture, and especially of logging, by which chutes have been formed on many steep slopes.

At Painter a few years ago the Tuckasegee swept away its north bank and shifted its channel so that it left the north end of the iron bridge that spanned it standing in what then became the middle of the river. The building of rock walls and planting of trees have not as yet repaired the damage caused by this change or effectually regulated the river's course.

The highest flood known at this point is said to have occurred in 1840; one in 1867 was nearly as high, and the next highest was in 1876. Though recent floods have not been as high as these earlier floods, it is asserted that their average height is greater than that of the usual flood of former years, and that their destructive powers have been increased by the greater velocity of the flood crest combined with its greater average height. This greater velocity with which floods pass a given point is due to the more sudden gathering of the storm waters from tributaries and the consequent increased steepness of the front slope of the advancing flood wave or crest as well as its greater height. This increased steepness of the front slope of the advancing flood crest and its greater velocity cause a more rapid rise at any given point than formerly and a more rapid fall to ordinary stages.

General conditions along the flood plain of any stream represent the effects of the high floods that occur every year or every few years rather than those of the extremely high floods that occur once or twice in a century—floods due to an extraordinary combination of circumstances. The evidence is as yet too scant—for few such floods have occurred since the white man occupied the region—to determine whether or not they show tendency to become higher as man works his changes in the valley.

Cullowhee Creek has a flood plain 400 to 700 yards wide, which is entirely cleared and under cultivation and is fairly fertile. Some 75 per cent of the bounding slopes, up to an elevation of 200 to 400 feet above the stream level, are also cultivated, and those that have long been cleared show the effects of erosion. Above these fields the mountain slopes become steeper, and in many places bold ledges or precipitously rounded masses of gneiss project. Such a projecting mass causes the falls on the Tuckasegee.

The crest of Cullowhee, Big Ridge, and other mountains in the vicinity have gentler, more rounded slopes than those above mentioned, and there are usually extensive clearings that in places have a thin, poor, gravelly soil, and in other places a soil that is more compact and fertile. The general condition as regards erosion on these high clearings is satisfactory, though in some places where they are steep and have long been cleared they are seamed with gullies. Such slopes need reforesting.

From Cullowhee Gap to Norton and on to Highlands the small streams have, as a rule, narrow flood plains, many of which are quite poor. They are not eroding to any marked extent, as practically all of the steep slopes up to the higher mountain crests are in timber. In this entire basin the clearings possibly amount to as much as 2 per cent of the total area. The

soil is a loose, light-colored, coarse-textured granitic sand or gravel. The timber is generally poor and thin. Some of the streams have a fall so slight that they are bordered by extensive swamp areas—as, for instance, in the valley of Big Creek, just north of Highlands.

Many of the higher mountain masses in this region, such as Whiteside, Scaley, Satulah, Fodderstack, and Black Rock, show extensive areas of bare precipitous granite surfaces that have been produced and rounded by subaerial erosion; and in other extensive areas the bare rock surface is concealed beneath only a foot or two of soil that is held together by a dense turf-like matting of rootlets from the vegetation upon it. When such areas are cleared these rootlets rapidly decay and disappear, and in a few years the thin soil cover is swept away and the bare granite is exposed. Once this condition is reached the area becomes permanently worthless, since hundreds of years would not suffice to reproduce a soil cover. The scarp-like eastern face of the Blue Ridge shows many more of these steep, bare granite slopes or domes than the gentle western slope, and the damage from further clearing in those slopes would be immediately felt along the streams that flow southeastward to the Atlantic and furnish along their way tens of thousands of horsepower that has already been or is now being developed electrically to run the many mills and furnish light and power for the towns of the Piedmont Plateau in the two Carolinas.

FROM HIGHLANDS SOUTHWESTWARD TOWARD RABUN GAP, GA.

For a number of miles the road from Highlands to Rabun Gap lies on the very crest of the Blue Ridge, and from many points along it there is visible to the west a gently sloping and deeply dissected plateau, above which here and there residual mountains rise, while to the east there is a precipitous descent of 1,000 to 2,000 feet to stream basins that lie but little above the level of the Piedmont Plateau. The scarp-like character of the eastern face of the Blue Ridge is perhaps as well developed in the Highlands region as anywhere in its entire course, unless it be near Roaring Gap, N. C., and many of the scarp slopes consist of bare granite precipices—as, for example, the east face of Whiteside Mountain (Pl. II, p. 16). The Blue Ridge crest in this region is made of a granite which weathers to a loose, porous, light-colored, and very poor soil. For a number of miles there are no clearings. Along the road south of Mount Scaley there are a few farms. Within the next 2 miles recently cleared fields are in good condition, but old fields have worn thin and are abandoned. They are not gullying or washing away to any marked extent but become poor as soon as the humus is exhausted.

The many small streams crossed between Mount Scaley and the valley of the Little Tennessee are swampy and forested on their upper portions, but along their middle and lower courses are bordered by narrow bottom lands that are cleared and farmed. In some places the gentle side slopes are cleared up to 100 to 200 feet above the stream level, but in others these slopes are in unbroken forest. The streams themselves flow in relatively deep channels and there is no evidence of damage from floods. All of the higher slopes and ridges are timbered, and there has been almost no lumbering because of a lack of transportation facilities.

RABUN GAP TO BUSHNELL.

In the valley of the Little Tennessee, 2 miles south of the North Carolina line, numerous remnants of a high flood plain stand 60 to 80 feet above the present stream level. The river valley at this point is unusually wide, with lower slopes of gentle gradient and a flood plain averaging half a mile to a mile in width and remarkably level. This flood plain has a rich soil and is practically all cleared and under cultivation. The stream flows in a channel from 3 to 6 feet deep, and has but very slight gradient. It was somewhat swollen when seen, and the water was discolored from vegetable matter and not reddened by clay particles. Overflows because of the shallowness of the stream bed are of frequent occurrence, but though they sometimes wash the bottoms they more commonly leave deposits of rich sediment and are regarded as beneficial rather than injurious. The river maintains this general character down

to Franklin, N. C., though the flood plain is in places contracted to a width of a few hundred yards.

Below Franklin the Little Tennessee flows across upturned edges of schists or other rocks that have resisted disintegration and erosion much more effectively than have the granitic rocks above Franklin. These weaker rocks in its upper valley have doubtless always weathered more rapidly than those below, and the river in its upper portion has always maintained as low a gradient as would enable it to remove the water and waste of its basin. The remarkably low grade from the head of the stream at Rabun Gap, Ga., to Franklin, N. C., has prevented floods from having sufficient velocity to injure the bottoms, and the unusual width of the flood plain, by giving a large cross section to these floods, has contributed much to the same end. The valley walls have weathered back with equal ease, and as a result the upper portion of the valley is unusually broad. This broadening has been produced by subaerial weathering and rill erosion rather than by cutting on the tips of meander curves by the river itself. Such meander curves are in reality most notable for their absence here, and it seems certain that the river has not widened its valley by this process. By the slow retreat of the valley walls material has been furnished to the main stream for building its present flood plain, and with its low gradient it is now just about able to remove the silt furnished from its wooded slopes. Once these slopes have been cleared, however, not only a much larger quantity, but much coarser kinds of waste will be furnished to the stream, and the present delicate adjustment of load to transporting ability will be destroyed. The stream will quickly become overloaded and will be forced to deposit the excess of load, first in the stream channel, but when that is practically full it will spread over the present fertile flood-plain surface, and by aggradation with barren clay and sand and rocky waste it will bury and ruin the only really fine agricultural lands in the region.

Here and there along the valley sides a flat-surfaced terrace, 60 to 80 feet above stream grade, is very prominent. In many places the surface of this terrace is covered with rounded bowlders, the largest 1½ feet in diameter: in other places a rich, deep red, loamy clay overlies the bowlder bed, which is here and there cemented with iron crusts but not so thoroughly as to prevent good underdrainage. These terraced lands are above the reach of floods and if properly cared for may easily be kept in a high state of fertility, but in many places their edges and the scarp down to the present flood plain have been abandoned as worthless. Above the level of this old terrace parts of the lower 100 to 200 feet of the valley wall have been cleared, farmed for awhile, permitted to erode, and then been abandoned, so that in this region there are many old fields covered by briars, persimmon trees, and scrub timber.

Between Otto and Franklin 60 to 75 per cent of the slopes have been cleared, and one-fifth of the cleared area is worn and old. About half of this worn land is deeply gullied; the other half has been washed down to the underlying barren clay by sheet flood erosion.

Franklin is on the old river terrace, which is there 80 to 100 feet above stream level. Its surface is of deep red loam, underlain by a cobble bed. On the east side of the river the same terrace level is also prominently developed, is cleared, and is in good condition as regards erosion.

The valley above Franklin contains here and there projecting knobs, 100 to 200 feet high, which are unreduced remnants dating from the time when the now fossil flood plain was the living flood plain. Some of these residual knobs have been cleared, but most of them remain wooded.

At the bridge over the river at Franklin floods have caused some slight damage, and here and there, especially on curves, there has been some erosion, though as a rule the flood plain of the Little Tennessee is remarkably free from such damage. A short distance below Franklin the valley walls close in on the river, and where any flood plain exists it forms either narrow border strips, in many places of coarse sand or cobbles, or here and there larger areas on the concave sides of bends or near the mouths of tributary streams.

Through much of the distance from Franklin to Bushnell the stream flows in a narrow gorge without flood plain. It is broad and shallow and is actively eroding the upturned edges of the ancient schists which are exposed along nearly all of this distance.

The road from Franklin northward to Watauga Gap runs for a number of miles on the old Asheville Plateau level, and its dissected and rounded surface shows the usual features of clearing, erosion, and abandonment.

Along Cat Creek there is very little bottom land, and comparatively little erosion has taken place. On the upper part of Watauga Creek the bottoms vary in width from an exceedingly narrow strip up to 100 yards. Not more than 5 per cent of the bottoms have been destroyed by floods in recent years, although the lower parts of the bounding hill slopes have largely been cleared and many of the fields have been worn out by erosion and abandoned. Three-fourths of the abandoned clearings are so gullied or so thoroughly stripped of their soil as to appear practically irreclaimable; on the remaining fourth vegetation seems to be catching hold and erosion is being slowly checked. Near the head of the creek clearings exist, especially on the eastern side near the top of the ridge, and all these high fields have been badly gullied. The freedom of the bottom lands from serious injury, under such conditions of erosion of the valley walls, can be attributed only to the sharp gradient and deep channel of the stream, which favor the rapid removal of flood waters.

North of Watauga Gap cleared lands extend almost continuously down Savannah Creek. Many of the clearings extend high up the valley sides, and practically all of the older fields have been injured by erosion. The inhabitants claim that it is easier to clear new fields than to keep the old fields from washing, and they accordingly cultivate the land as long as it is possible, usually 6 to 10 years, then abandon it and clear another field by its side. The lower portion of Savannah Creek has a relatively narrow flood plain, and the stream channel is so filled with sand and gravel that ordinary rains produce floods that cover the bottoms and destroy the crops. Five such destructive floods had already occurred in the summer in which the examination was made, and many fields have been ruined and growing crops killed by the deposit of sand and mud. New channels are frequently cut during such floods.

Much of the land along Johns Creek, a tributary of Caney Fork, in the eastern part of the county, has also been cleared. Erosion and abandonment of the valley slopes is common, and conditions are reported to be almost as bad as in the basin of Savannah Creek.

Webster, at an elevation of 2,188 feet above sea level, is on the deep, red soil, with underlying bowlder bed, which characterizes the old high flood plain found on the Tuckasegee. From Webster northeastward to Hall the slopes of the old dissected plateau level consist chiefly of red clays resulting from the disintegration of granite. Many of these slopes have long been cleared and in a number of places they have been abandoned because of erosion. Recently cleared fields, that are as yet in good condition, are numerous, but in a few years they, too, will begin to erode.

On Forneys Creek, which enters the Tuckasegee just above Bushnell, there are only a few farms, and on the high slopes but two clearings were observed. On the lower slopes, just above stream grade, there are a number of small clearings. The land was not being damaged by erosion. The proportion of cleared lands in the basin was entirely too small to affect floods on the stream itself, so that the narrow bottom lands were in satisfactory condition as regards erosion.

FROM BUSHNELL DOWN THE LITTLE TENNESSEE.

For some miles below Bushnell the Little Tennessee is bordered in many places by narrow flood-plain strips that extend for some hundreds of yards. Most of these areas are of medium fertility, and they have not been seriously injured by the river. It is generally believed, indeed, that floods benefit the lands by depositing sediment rather than injure them by erosion. In a few places rock walls have been built parallel to the stream channel. Behind these, sediment has accumulated to depths of 8 to 10 feet. From a point a short distance below Wayside through the mountain gorge to the Tennessee line the river has practically no bottom lands.

The valley is narrow and its sides are rough and steep and scantily timbered. The soil on the few cleared areas is full of stones and is too poor and dry to be of much agricultural value. The stream itself flows with a broad, shallow, swift current over the upturned edges of conglomerates, quartzites, and slates. Here and there are rapids that would seem suitable for power development, and between the rapids there is an occasional deeper pool—such, for instance, as the one at Rocky Point Ferry.

All the tributaries, except the larger ones, such as Hazel and Eagle Creek, enter the Little Tennessee by a series of rapids, along which their valleys are narrow gorges; but some miles back from the river, where their steep gradient has raised them to the old plateau surface, their valleys are broader and in many places have been extensively cleared and cultivated. Most of these broader valleys have gentler slopes than those farther downstream and have not been greatly eroded.

Panther Creek, which enters the Little Tennessee about 4 miles west of Bushnell, is bordered along its middle and upper course by areas of good bottom lands, which are for the most part cleared. Its basin slopes are practically all in forest, and its flood plain showed no damage from floods. A lumber company has, however, built a tramway from Judson, and has prepared to log the entire Panther Creek basin within the next few years.

Along the middle courses of both Sawyer and Tuckasegee creeks are considerable areas of fertile agricultural land, much of which has been cleared and is in satisfactory condition as regards erosion. The upper portions of these creeks and the upper slopes of their valley walls, as well as the entire area of their lower or gorge stretches, are in forest.

Hazel Creek has been cleared from a short distance above its mouth practically to its head, both along its bottom and up the sides of its valley. These valley-slope fields are thin when not properly cared for, but do not gulley deeply. Throughout all this region, where the rocks are conglomerates and slates, the soils as a rule are porous and are filled with small, unweathered pieces of stone. Such soils, it has been found, rarely erode badly.

On Eagle Creek the land is poorer than on Hazel Creek, and the slopes are rougher, so that clearings are unimportant. There is little or no bottom land.

From Rocky Point Ferry the road up Cheoah River runs for a number of miles along the poor, dry ridge of Yellow Creek Mountain. Four or five families live along the road between the ferry and Yellow Creek, but their clearings aggregate less than 100 acres. The lands are poor and sandy and do not wash badly.

CHEOAH RIVER.

From Johnson to its mouth, a distance of 7 miles, Cheoah River flows in a narrow, rocky gorge and has a fall of some 700 feet. It is bordered by no flood-plain areas, and the steep sides of its gorge are uncleared. The mountains west of the river to the State line and beyond are practically untouched by the ax, not a single clearing being visible from Yellow Creek Mountain.

Above Johnson the valley of the Cheoah broadens, and the river has developed a flood plain of varying width. This flood plain has not been damaged by erosion. Along this portion of the river there are preserved many remnants of the old Asheville Plateau surface, which here rises 100 feet or more above stream level and has been largely cleared. The higher mountain slopes are almost entirely in original forest.

Yellow, Buffalo, and Mountain creeks have narrow flood plains, all of which are in cultivation. The streams are as a rule meandering, but they have deep channels and are doing little, if any, damage. Numerous low, flat-topped terrace spurs, 20 to 60 feet high, project from their valley sides. Many of these have been cleared, and in places their steep slopes are eroding. The gullies formed are narrow, shallow, and stony.

All small streams in the region from Bushnell down the Little Tennessee to the mouth of the Cheoah, and the Cheoah itself and all its tributaries, were clear when examined, and it is certain that in this immediate region no extensive erosion is in progress. With the completion of the railway down the Little Tennessee, however, transportation facilities will be

furnished for the shipment of lumber, mills will quickly spring up, and in a few years all the timber of merchantable size and quality will have been removed. It will be interesting to note the changes produced in the streams as a result of the changed conditions brought about by the lumbering.

NANTAHALA RIVER.

In the lower 5 miles of its course the Nantahala flows in a narrow gorge whose walls are but a few hundred feet high, but in the next 12 to 14 miles upstream its gorge is one of the deepest and most precipitous to be found in western North Carolina. A portion of the valley wall at Hewitt rises 2,000 feet above the stream and is exceedingly steep. In this stretch of the stream there are no flood plains worthy of mention, and the valley walls are uncleared. They have, however, been extensively lumbered, for transportation is readily accessible by the Murphy branch of the Southern Railway.

The upper part of the valley of the Nantahala is broader, and its walls are more irregular and retreating and are much dissected by numerous tributaries from both sides, but the flood plains comprise only isolated tracts, a few acres in extent, lying near the mouths of tributaries or within meander curves. Even such areas are not, properly speaking, flood plains, but rather beveled plains, of which only the lower edge is ever in reach of floods. The stream is actively eroding its channel and is constantly undercutting on curves and shifting its position, thus beveling its floor. These beveled valley slopes are best developed just above and below Aquone. They are only moderately fertile, and their aggregate area is not great. Above Aquone much of the valley is without flood plain of any kind. From Aquone up to Wallace Gap road the basin has been lumbered, but above this road the forest is practically untouched. A few families live in the upper part of the basin, but the aggregate cleared area is so small as to be negligible.

Between Aquone and Burningtown Gap the numerous small streams are bordered by narrow, sloping, semitorrential flood plains, which are relatively fertile and in good condition as regards erosion. All of the higher slopes are in timber. In Burningtown Gap there are some old fields, long since turned into pasture, which are still grazed and are holding remarkably well. East of the gap, part of the amphitheater-like head of Burningtown Creek had recently been cleared, and when examined its steep slopes were in corn. The soil contained abundant humus and showed no erosion. Lower down the valley walls close in, and the creek flows for some distance in a narrow gorge, beyond which the walls retreat and a torrential flood plain about 400 yards wide has been built. Still lower the slopes again close in, and in this alternating fashion narrow gorge and broad flood plain succeed each other well down to the mouth of the stream. The middle and lower portions of the valley contain remnants of the old plateau surface, some of which are cleared and others are entirely wooded. The higher valley walls are everywhere wooded except at the head of the stream. The valley is in good condition as regards erosion.

HIWASSEE RIVER BASIN.

GENERAL FEATURES.

The basin of the Hiwassee, the most southerly stream tributary to the Tennessee from the Carolina mountains, lies immediately southwest of the Little Tennessee basin and extends northwestward from the Blue Ridge to the point where the river enters the Tennessee, some 30 miles above Chattanooga. It is about 85 miles long, varies in width between 35 and 50 miles, and comprises 2,725 square miles. Like the basins to the north, it consists of an upper mountainous portion, in which the river is torrential in character, and a lower valley portion, in which the stream flows with deep channel and low grade. The river is navigable for 35 miles, from the mouth of the Ocoee, its chief southern tributary, to its junction with the Tennessee, and is traversed by a regular line of steamboats. Many appropriations have been made by the Federal Government for the improvement of its channel.

UPPER HIWASSEE RIVER.

FROM THE HEAD TO HAYSVILLE.

On its northeastern side the upper or mountain part of the Hiwassee basin is made up of a succession of mountain ridges and intervening tributary valleys, but southwest of the river, between it and the Ocoee, much of the old plateau surface is preserved.

The southeastern end of the basin, along the Blue Ridge, does not rise gently to the ridge crest as do the basins of the streams farther north, but is walled in by a distinct mountain ridge, which separates it from the Tallulah and Chattahoochee basins. The divide on the southwest, separating the Hiwassee basin from the headwaters of the Coosa River system, is much lower and more irregular, having, in fact, no marked prominence anywhere, and in some places it would be crossed without being noticed as a divide, as, for instance, at Blue Ridge, Ga., on the Louisville & Nashville Railroad. On the northeast the divide between the Hiwassee and the Little Tennessee is well defined and reaches altitudes of 4,000 to 5,000 feet above sea level. The upper mountainous portion is sharply delimited on the west, where the stream cuts across Beans Mountain and enters the broad valley of east Tennessee.

At its head the Hiwassee has no flood plain and all the steep slopes are in forest, but within 2 or 3 miles of Unicoi Gap a small flood plain begins, which gradually widens until it is from a fourth to a third of a mile wide. It is usually 6 to 10 feet above stream level, is fertile, and is cleared and cultivated. The stream itself is swift and clear, and flows over either bedrock or gravel bars, interspersed here and there by deep pools. This flood plain shows an occasional washed area on the inside of a bend or near some bridge abutment or other obstruction, but under usual conditions it does not show erosive damage, and the stream as a whole can not be said to be injuring its bottom lands more than would be expected of any stream subject to floods. During floods, indeed, many parts of the flood plain are improved by a deposit of silt.

On the high slopes of Rocky Mountain, near the head of the river, one tract comprising 30 or 40 acres has been cleared and farmed, but half the cleared land has been worn thin and gullied to some extent, and part of this has been abandoned. Except for this farm the slopes are uncleared down to within 100 to 200 feet of stream level, and throughout much of the distance down to Murphy not more than 30 to 50 per cent of these lower slopes has been cleared. The valley has long been settled, and many of these hillside fields are old and worn and in places have eroded badly and been abandoned.

Along the valley sides many remnants of old stream terraces are visible. They are not all at the same level, but represent several distinct terraces and indicate pauses in the down-cutting of the stream. In the upper part of the basin these terraces range from 12 to about 60 feet above the present flood plain, and in some places remnants of the terraces at two levels are to be found either adjoining or within short distances of each other. The height of the terraces, especially that of the higher, shows some slight increase down the stream, so that this old flood plain is to-day more nearly horizontal than the present flood plain. Almost everywhere these high terrace remnants are covered with a deposit of red clay, beneath which is a bowlder bed from 1 foot to 3 feet thick. The bowlders are rounded stream cobbles, most of which are less than a foot in diameter, though a few are larger. Many of these terrace remnants are flat topped and slope in an irregular, undulating manner to a lower level, and the connecting slope is as a rule cobble strewn. The margins of these terraces are in many places steep sided, and those long cleared are especially likely to be eroded.

At Mountain Scene a prominent, well-defined 60-foot terrace is connected by an irregular scarp with a terrace at a 10 to 12 foot level. At Buck Knob there is a well-preserved terrace, whose higher portions are 50 feet above the present flood plain, but slope irregularly down to a height of 30 feet. Just below Presley is another well-developed terrace with a broad, sloping, cobble-covered surface, whose upper and lower limits are 75 and 55 feet, respectively, above the present flood plain. Two miles farther downstream there is a still more perfect

terrace, 75 to 100 feet high, which is undulating and irregular on its streamward edge and which rises by a gentle slope to its junction with the valley wall. A portion of the same terrace is also well developed across the river to the west.

At the town of Hiwassee the upper limit of this old stream terrace is about 1,994 feet above sea level. The present flood plain is about 1,875 or 1,880 feet above sea level. The vertical interval between this high terrace and the present flood plain has therefore increased from about 60 feet, along the upper part of the river, to at least 115 feet at Hiwassee. Further increase in this vertical interval downstream is exceedingly slow, if, indeed, the interval of more than 100 feet is maintained at all, since the elevation of the terrace is a function, at least in part, of valley width, being higher where the valley is narrower and lower where broader.

Next to the present flood plain these old high or fossil flood plains are the most fertile lands in the region and are the best adapted to agriculture. They were cleared very early in the settlement of the valley and many houses and barns have been built on them, as they furnish level ground well above the reach of floods. Where their surface is relatively level they are not eroded, but erosion has caused considerable damage in many places along their steep-scarped edges. The worst examples of such erosion were seen about Buck Knob, but as this steep scarp is relatively narrow the total area of land so injured is correspondingly small, and it might be protected by terracing the lands cultivated on it.

North of Hiwassee the river valley broadens greatly and the present flood plain is 8 to 15 feet above water level and occupies but a small part of the width of the valley. Above this flood plain an irregularly sloping terrace that contains rounded cobbles rises to an average elevation of 100 feet. This old terrace is surmounted by many low domes, peaks, or ridges that stand 100 to 200 feet higher and are residuals formed when the old high terrace was a living flood plain. They are very much like the residuals found on the upper French Broad at Brevard and on the Little Tennessee at and above Franklin, have had the same history, and are of the same age. Like them they are largely uncultivated or when long cleared have been generally eroded, because their sides are steep and their soil is a well-decomposed clay. The residual clays here, however, do not show a tendency to deep and rapid erosion with undercutting and the production of broad, vertical-walled flat-bottomed gullies, but cut into numerous narrow, shallow, V-shaped trenches.

Near the Georgia-North Carolina State line there is a low terrace, 25 to 30 feet above the present flood plain, and another terrace at 100 feet; remnants of the two terraces may also be distinguished at several places farther down the valley.

Haysville is on an old terrace which is there 80 feet above flood-plain level, and many other remnants of the same terrace are visible near by. These have been largely cleared, and many of them are worn out and abandoned, but they are commonly covered with briers and bushes, which are slowly checking erosion and preparing the way for a future forest cover.

FROM HAYSVILLE TO MURPHY.

Valley River heads in Red Marble Gap and flows southwestward in an almost direct line to the Hiwassee at Murphy, N. C. Its valley is, as a rule, broad with very gentle slopes on both sides. These gently sloping valley sides have been deeply trenched by many small tributaries of the river, and the projecting spurs between the streams reach down well toward the river itself and end in elevations of a few hundred feet above the valley floor. Between the ends of these projecting spurs on either side of the river there is a flood plain a mile to 2 miles wide. The river flows along a belt of marble, and the width of its flood plain varies with the width of the outcrop. Where this belt is widest the valley is broadest; where it is narrowest the valley is narrowest. Practically all of the valley walls are forested, although in most places the lands have been lumbered.

The flood plain of Valley River is almost everywhere cleared. A tract of varying width lying next the stream is covered by ordinary floods, but as the stream gradient is low its flood

velocity is so slight as to prevent material damage. This flood plain is bordered in many places by an old terrace whose upper surface is quite irregular and varies on its flood-plain edge from 10 to 20 or even 30 feet in height, but back from its streamward margin slopes gently upward to an elevation of as much as 150 feet in places where it joins the valley walls. This slope is commonly cobble strewn and is plainly an old beveled flood plain or slope made by the stream while cutting vertically and swinging laterally at the same time. This old terrace comprises some excellent farming lands and is nowhere being greatly eroded. In very few places were any of the valley walls above this plain cleared, and generally only a small amount of clearing has been done along the tributaries of Valley River. In its lower course the gravels of both the living and the fossil flood plain contain some gold, and considerable hydraulic work has been done.

On Hightower Creek there is some good bottom land at Osborne, but the largest and best area is some miles above, near Visage, though narrow bottoms extend well up to the head of both the main stream and its tributaries and are for the most part cleared. Practically all the slopes are in forest. No considerable areas have been cleared, even on the lower valley side, of either the main creek or its tributaries. At the very head of the creek, on the dividing ridge, are some recent clearings which have not yet begun washing as they are likely to do as soon as the humus has disappeared from the soil. Bottom lands along the creek have in recent years been slightly damaged by floods, but the damage has not been greater than may normally be expected on any stream similar in gradient and rainfall.

The forested slopes have been purchased by lumber companies, it is reported, at an average price of $1 to $2 per acre. Until a railway can be built some 30 miles up the river from Murphy no extensive logging can be undertaken.

Practically all of the slopes in the basin of Shooting Creek are wooded, and little or no lumber has been cut except for local needs. The bottoms along the stream are cleared and farmed, but the stream channel is deep, the current is relatively swift, and floods have not been serious. The forested slopes have, like those on Hightower Creek and elsewhere in the upper Hiwassee basin, passed into the hands of lumber companies and doubtless will before many years be extensively lumbered.

The flood plain on Tusquitee Creek is rather broader and better than that on Shooting Creek, and the bordering slopes are even less cleared. No damage has been done by floods. The timber in this basin also has been sold.

Fires Creek drains a very steep-sided basin, much of which is rough and practically all of which is wooded. The residents of the basin comprise only a few families, and their aggregate clearings are very small. There are scarcely any bottoms along the stream itself, and there has been no damage from floods.

During the examination of this region it was accidentally discovered that the United States Government owns tracts of timber land in this basin and in the basin of Cheoah River west of Robbinsville. It is estimated that good titles may still be had to some 32,000 acres. The existence of such Government holdings seems to have been practically lost sight of, as the title is lodged with the Treasury Department and not with the Land Office. The land is said to have been seized as one of the assets of a defaulting contractor. A request was sent by the writer to the proper officials urging that these lands be withheld from sale and retained as a nucleus for a possible forest reserve.

Along Brasstown Creek there are some good bottom lands which are bordered in many places by the old high terrace and by rolling hills whose higher slopes are wooded. No flood damages are reported there.

Between Haysville and Murphy a flood plain is lacking in a few places where the river cuts across resistant rocks, but more commonly it is present and is broad and fertile. Near the mouth of Peachtree Creek it is from three-fourths of a mile to a mile wide. Many remnants of the old high terrace are visible above it. A mile above the mouth of Brasstown Creek and on the opposite side of the river, where the present flood plain is relatively narrow, a terrace is

well preserved at an elevation of 60 feet. At the mouth of Peachtree Creek, where the river flood plain is very much broader, an admirably preserved terrace, that is regarded as of the same age as the terrace just mentioned, has an elevation of 40 to 50 feet above the present flood plain, the decrease in elevation being due to the greater width of the valley.

Up and down the river and up the valley of Peachtree Creek there are many low, ragged-topped hills and ridges that rise 100 to 150 feet above the old terrace level. Most of these are timbered. On the sides of the valley the lower slopes are in some places cleared to a height of 100 to 300 feet above stream level, but in many places these slopes are wooded, although much of the best timber has been cut and rafted down the river to Murphy. Murphy is situated on the old high-terrace plain, which there stands 90 to 120 feet above the present flood plain and is bordered by a much more recent but quite prominent terrace at an elevation of 40 to 50 feet above the present stream grade.

FROM MURPHY TO THE MOUTH OF THE OCOEE.

For some 40 miles below Murphy the Hiwassee flows across the trend of the mountain structure in a narrow gorge-like valley cut to a depth of several hundred to a thousand feet or more. The stream channel is as a rule broad and shallow, the slope is so great that the current is swift, and the erosion of the hard rocks that form its bed, except where there are local gravel bars, is rapid. Combined with the present active down-cutting there is considerable lateral shifting due to frequent irregular meanders, and where small flood plains occur they are usually of the beveled or hanging type. Where the flood plains are flat the grade and the width of the stream are so great that floods rise but a few feet and flood-plain level is accordingly but a few feet above stream level.

At Murphy the river is 75 yards wide and the narrow flood plain is 8 to 15 feet above the stream. Just below Murphy the river enters a gorge and is bordered by a narrow sandy strip of flood plain that is not cleared. Just above the mouth of Nottley River, where the living flood plain is 5 to 8 feet high and the river is 100 to 150 yards wide, there is a prominently developed fossil flood plain 80 feet above the living plain; just below the mouth of the Nottley stream gravels are found up to an elevation of 130 feet, but no well-developed terrace is seen at this height. Ordinary floods are here rarely more than 3 to 5 feet high, and the highest recorded flood is said to have been 18 feet. The entire flood wave passes within 24 hours if rains on the headwaters have not been continuous. Floods do very little damage, as there is very little bottom land within their reach.

At the mouth of Great Creek the valley sides are only moderately steep, and up to an elevation of 200 or 300 feet above the river 40 to 60 per cent of them are cleared. These fields show scarcely any erosion, probably because of the slight slope and the somewhat porous, stony character of the soil. About 5 feet above stream level there is a well-developed ordinary flood plain some 10 yards wide, and 10 feet higher an extraordinary flood plain. Up Great Creek valley the hills are low and retreating and much of the area has been cleared, farmed until worn thin, and then abandoned. Some of this abandoned land is badly cut with narrow gullies.

Along the river for several miles below Great Creek the upland marking the level of the old river valley is largely cleared, its slopes are low, and it has not been greatly damaged by erosion. From just below Beaverdam Creek down to the State line the uplands have a poor, thin soil derived from the weathering of slates and schists. When such uplands are cleared they produce about three good crops before the humus of the original forest has disappeared. They then begin to gully and are soon abandoned. The tributary streams are in most places bordered by narrow and relatively fertile bottom lands which have locally been somewhat damaged by floods. The higher mountain slopes are in forest, but the forest is ordinarily thin because of the poor, dry soil. The best of the timber has been culled and hauled by wagon to Murphy.

Along Coker Creek the soil is for the most part poor, as it is derived from the weathering of slates or schists. All of the higher slopes are wooded. A large part of the lower slopes were once cleared, but their fertility was soon exhausted, and they were abandoned to grow up in bushes, briers, and broom sedge. Along the stream itself most of the scattered flood-plain areas have a poor soil. In many places these areas have been torn up by placer gold mining. Gold occurs sparingly in the gravels of this stream basin and has been mined in a desultory way for nearly a century.

From Coker Creek westward to Springtown and from Springtown southward to the river wooded ridges alternate with narrow stream valleys. The bottoms and in places the lower slopes of the ridges are cleared and cultivated. The soils are as a rule thin, and those on the slopes are generally eroded to a considerable extent except where they are freshly cleared. The aggregate area of cleared land is, however, small. Along the streams near Springtown the lower 75 to 100 yards of the slopes are gentle and are more largely cleared. The soil is poor and slaty, and as soon as the original humus is exhausted it begins to erode, so the old areas are constantly being abandoned. Just at Springtown the soil is derived from limestone and is more fertile, but it is also more easily eroded.

On Hiwassee River just below the mouth of Childers Creek there is a fertile flood plain 250 to 300 yards wide, which is 6 to 10 feet above stream level and has not been greatly damaged by floods. In the river are several islands that are stable or are slowly growing and are protected from erosion by a fringe of willows around their edges. Their soil is fertile and is cultivated.

LOWER HIWASSEE BASIN.

The lower or valley part of Hiwassee River was not examined in detail. Below the mouth of the Ocoee the river is navigable, but navigation is interfered with to some extent by sand and gravel bars. Government employees engaged in maintaining a channel report a constant tendency of the sand and gravel to refill channels once dredged or cleared. The writer believes that this tendency on the Hiwassee is not as marked as on some other streams of the Tennessee system, because the Hiwassee does not carry as great a volume of coarse débris as is carried by the Little Tennessee, the French Broad, and other tributaries. The amount or débris carried by the Hiwassee must, however, increase with the increase of lumbering and of clearing in its middle and upper basins, and much of this added material must find at least temporary lodgment in bars and islands and thus become a constantly increasing obstacle to the maintenance of a navigable channel.

Ellis Creek has opened a steep-sided valley along a narrow belt of upturned limestone. Its valley slopes are cleared for a short distance above stream level, and the clay surface is being cut into many narrow, sharp-bottomed gullies.

OCOEE RIVER.

From Ellis Creek to the mouth of Caney Creek, on Ocoee River, the small streams are bordered by narrow bottom lands that are for the most part cleared. In some places where the lower slopes of the bordering uplands have been largely cleared these bottoms have washed badly. The sloping fields more than a few years old also show marked erosion and many of them have been abandoned. Here and there still higher slopes have been cleared and these, too, erode freely.

For 10 miles above the mouth of Caney Creek, Ocoee River occupies a deep, narrow, rock-bound gorge, in which it cuts its way in an almost continuous series of rapids. No flood plain has been developed in this distance and there are no mountain-side clearings. At the upper end of the gorge the valley widens and a flood plain has been built, but within recent years it has been covered by a deposit of barren sand and has thus been practically ruined for agriculture. This sandy material has been furnished by the abnormal erosion occurring about Ducktown (see p. 78), and deposition at this point is due to the ponding and checking of the flood current by the gorge below. The checking is just sufficient to cause the river to deposit

the sand, leaving in suspension the finer silt, which is thus carried through the gorge and deposited where the river assumes a much lower gradient as it flows out into the great valley of east Tennessee. The flood plain there built of this finer material is fairly fertile.

Above Ducktown the flood plain varies much in width but averages 100 to 200 yards. It is rather sandy and only moderately fertile, and is being damaged to some extent, especially along its streamward edges, by the floods of recent years. Though tributary stream grades in the upper valley of Ocoee River are as a rule moderate, many low hills reach the old plateau level. In places these have been cleared, or much of the timber has been removed and runways have been opened that have resulted in a material increase in flood damages.

DUCKTOWN COPPER REGION.

Ducktown, Tenn., located in the southeastern part of the Hiwassee basin, is situated on an elevated and now deeply dissected plateau, presumably of the same age as the Asheville Plateau, and is walled in on almost all sides by mountain ridges. Copper is mined and smelted here, and in the immediate vicinity of the smelters all vegetation has been killed by sulphuric acid fumes. The region is peculiarly adapted for the study of erosion problems, since it affords an extreme example of the limits to which erosion may go in this climate when all protective vegetation has been removed. One smelter began operations about 12 years before the region was examined; another had started only 4 years previously; the complete destruction of vegetation had taken place within the latter period. During this short time the second-growth timber and the bushes and grass beneath it, which had covered most of the area, had been killed, and the dead trees had been removed for firewood; but though the ground is in many places still covered with small branches and twigs, the litter-covered surface is already cut to pieces by erosion.

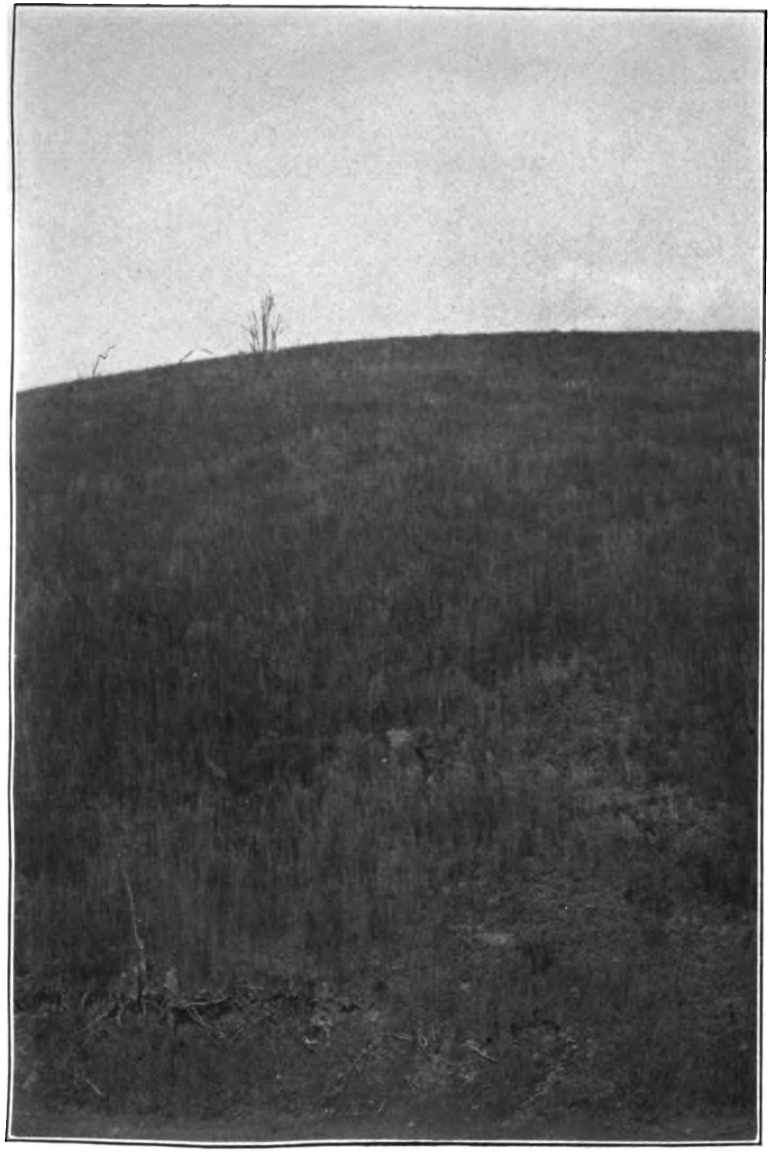
The erosion starts near the bottom of a slope, and where the soil is porous rapidly cuts a steep-sided gully to a depth of 5 to 12 feet below the surface, where the underlying schist is as a rule still measurably firm. After a gully has reached its limit in depth it widens until its walls coalesce with the walls of adjacent gullies, by which time most of the soil has been removed. Where the soil is a more impervious clay, erosion begins, likewise, at the foot of a slope, and eats out amphitheater-like areas such as are shown on Plate XVI, opposite. Like the deep-grooved gullies, they rapidly grow headward until they reach the top of the hill and completely denude it. Hills gullied in these two ways are illustrated in the two views in Plate XVII.

The quantity of waste furnished by these bare slopes, being too large for the streams to remove, rapidly accumulates along the stream courses as flood or waste plains, which soon extend up even to the foot of the slopes at the head of the streamlets.

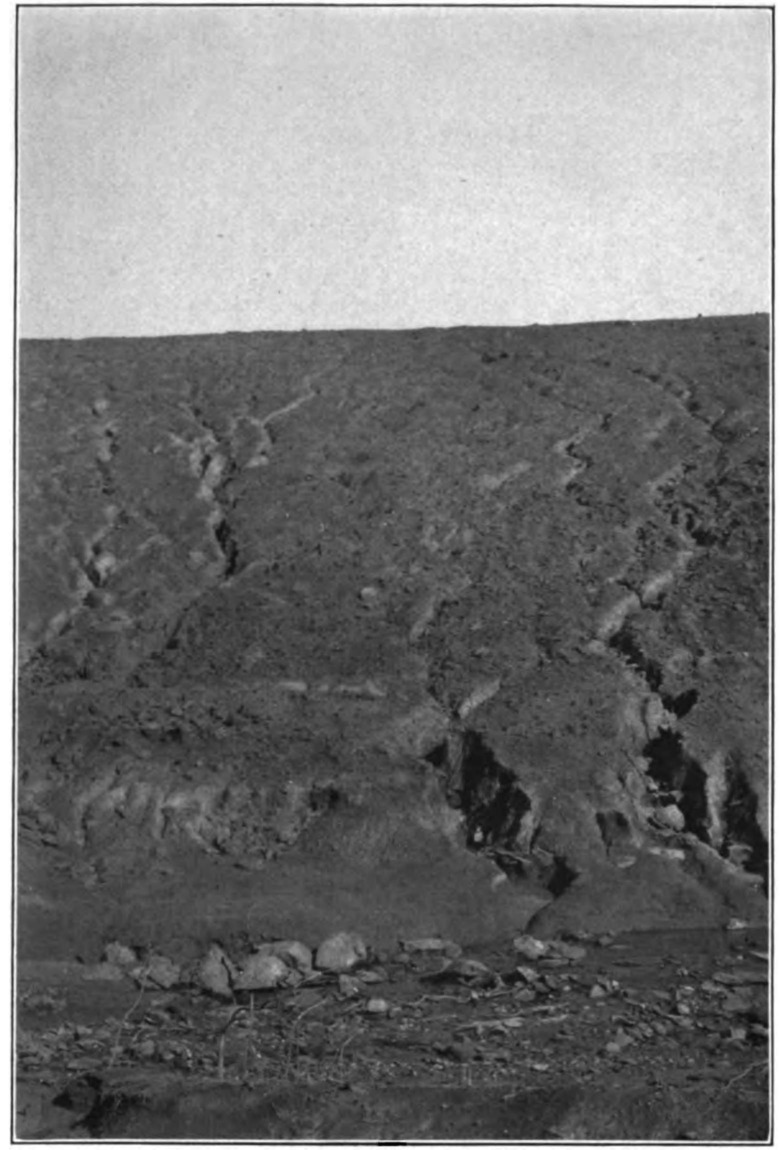
On Potato Creek this waste has been accumulating for a number of years at the rate of a foot or more each year, and has been built into a flood plain from 100 to 300 yards wide, in which telephone poles have been buried almost to their cross-arms, and highway bridges, roadbeds, and trestles have either been buried by the débris or have been carried away by floods. At Isabella smelter recent floods have swept through the store and other houses, and the waters have risen to the level of the furnaces. This increase in the height of floods is due largely to the rapid building up of the flood plain, and extensive diking or other protective measure will soon be necessary to prevent serious damage to the smelter and other property.

Such great quantities of sand are carried into Ocoee River by each large flood as to prevent the running of the two ferries at the smelter until the river has had time to scour its channel clear again. Much sand has accumulated on the flood plain of the Ocoee in the few miles just above the river's entrance into the gorge below Ducktown.

This abnormal denudation and erosion has also affected the underground water level in the region. During the last few years wells have been going dry, and a number of springs, some of which supply water to the miners' families, flow less than formerly. This lowering of the ground-water level and decreased flow of springs can not be attributed to drainage effected by



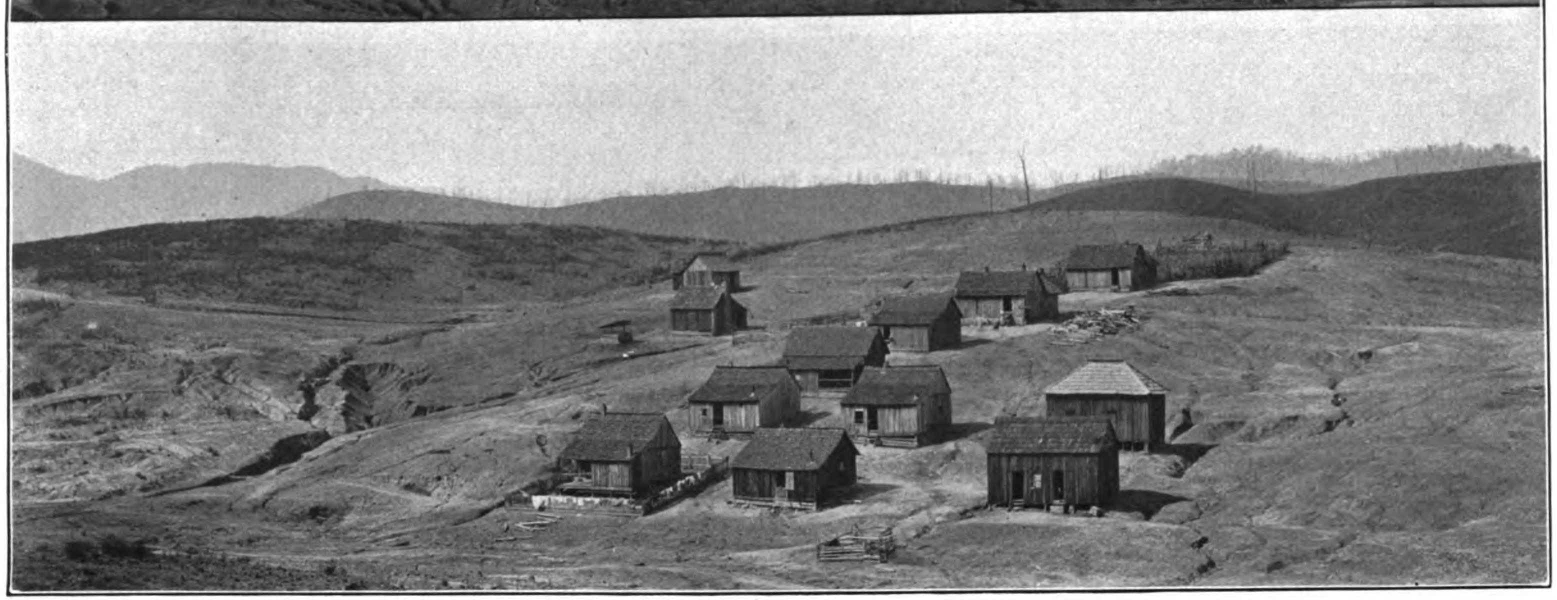
A.



B.

EROSION NEAR DUCKTOWN, TENN.

A. View taken several miles from Ducktown, where a broom sedge turf, yet living, has thus far prevented erosion. See page 45.
B. View taken nearer Ducktown. Surface has no protecting turf and is fast eroding. See page 50.



A. DENDRITIC EROSION NEAR DUCKTOWN, TENN.
B. SURROUNDINGS OF HOUSES NEAR DUCKTOWN, TENN.

See pages 19, 78.

A. DENDRITIC EROSION NEAR DUCKTOWN, TENN.
B. SURROUNDINGS OF HOUSES NEAR DUCKTOWN, TENN.

See pages 19, 78.

the deep mining shafts, for the mines are nearly dry. The normal flow of Potato Creek is said to be only about half as large as it used to be, and there can be no question that a much larger part of the rainfall now finds its way immediately into this stream and is carried off in floods, leaving a much smaller part to soak into the ground to supply the wells, springs, and streams during periods of dry weather.

Erosion about Ducktown to-day is limited only by the rainfall, the steepness of the slopes, and nature of the soil. The destruction of the soil on the slopes by erosion and of all of the alluvial land along the streams by flood-plain building is complete, and over an area comprising several square miles the entire country—flood plain and valley slope alike—has become a barren waste. The Ducktown region is, then, not only an impressive object lesson, but an emphatic warning of the extent and character of the disaster that may result in these southern mountains from the thorough destruction of the forests.

TENNESSEE RIVER PROPER.

GENERAL CONDITIONS.

A detailed examination was made of the Tennessee from Knoxville down to its mouth at Paducah, Ky., a distance of 650 miles, in order to determine what became of the abnormally great amount of rock débris being furnished by the steep slopes of the high Appalachians of western North Carolina to the many headwater tributaries of the river, and whether it was in any way interfering with navigation or with plans for the further improvement of the Tennessee River system. The Government has already spent in such improvements between $8,000,000 and $9,000,000, and in order to complete the plans prepared will be required to spend several additional millions. The river drains a territory that is rich in natural resources and contains important water powers, two of which, one just below Chattanooga and one at Muscle Shoals, are now being developed. The exploration was made in a small gasoline launch when the river was at its lowest stage and stops were made wherever they seemed desirable.

Through the courtesy of Maj. Newcomer, United States Army, then in charge of the improvement work, and of the several officers immediately responsible for the work on several sections of the river, sets of blue prints and tracings of detailed surveys and of the plans for improvement were obtained, together with much information as to present and past conditions on the river. With these maps and plans in hand and copies of all important Army engineer reports on the river, as well as a reconnoissance map of the lower river made in 1865, pronounced by an Army engineer in charge of work on the river to be very accurate, it was possible on this trip to study the river to great advantage, although even without the aid of maps or plans a very satisfactory study could have been made by noting the present condition and the general character of the changes now in progress.

Through much of its course, especially in its upper stretches, the Tennessee meanders irregularly. On the convex sides of curves it is generally bordered by bluffs, in many places of bare limestone; on the opposite side, within the meander curves, there are usually fertile flood plains, some of which terminate in gently beveled slopes that extend down into the meander curves. Where the stream is straight it is generally bordered on both sides by flood plains, whose height above ordinary water level varies with the width of the flood plain itself and with the width and velocity of the river, but ranges from 20 to 40 feet in the upper part and 30 to 50 feet in the lower part of the river. In many places there is a narrow ordinary flood plain, which is usually bordered by a much broader extraordinary one whose soil is poorer and whose undulating surface has been produced by incipient erosion, for on these extraordinary flood plains destructive forces have become more powerful than constructive forces. At various higher levels there are cobble or gravel strewn remnants of still older fossil flood plains that exist now as more or less prominent terraces.

Islands are numerous along the entire course of the river and, except where conditions have been affected by the building of Government dams or other regulative works, are generally

growing. The growth is, as a rule, especially rapid on the upper end of the island and on one side or the other, but not on both sides. Some islands also grow at the lower end. This upward and lateral growth of the island causes constantly greater deflection of the river current, which in turn produces changes in the position and depth of the channel and in the configuration of the opposite bank. Along the upper course of the river the growth of the islands seems to be more marked just above Chattanooga than just below Knoxville.

As a rule the surface of these islands is fertile and is cultivated wherever it is high enough to be reasonably safe from ordinary floods. Many of the better managed of these island farms have been protected from erosion during floods by a fringe of timber planted or preserved around the upper ends and down the sides. In some places floating material lodges in great rafts in this fringe of timber during floods and by the powerful scouring action of the strong current deflected beneath it causes extensive gouging on the upper end of the island. In other places the river shows a marked tendency to deposit gravel on the sides of the island just below the point where the currents are deflected away from it. These lateral accumulations, whose lower ends may project downstream as sharp pointed barbs or spits, generally become attached to the islands and are the chief means of lateral growth. Slow alterations in the shape of the upper end of an island and of the gravel bar that usually extends upstream below water level for some distance rarely permit the chutes formed on either side of a growing island to remain unchanged. Fortuitous changes in the growth of the island deflect the current more and more to one side or the other and cause a gradual filling of the abandoned channel. Thus in time, by a lateral shift of channel that involves serious property losses on one bank and concomitant gains on the other, the island becomes tied to the bank and ceases to be an island.

Most bars are made up of gravel and cobble and some bowlders. A marked decrease in the average size of the material composing the bars is easily observable in going down the river. Near Knoxville the bars contain many rounded cobbles a foot or more in diameter; at Chattanooga the average diameter of the largest particles is 3 or 4 inches or less; on the lower river the cobbles have long since disappeared and the average diameter of the largest gravel is an inch or slightly more. On the upper river the bars contain comparatively little sand; on the lower river they generally contain a large proportion of sand. Silt deposits are not prominent on the upper river, but are characteristic features of the lower river. The cause of these changes is easily understood. The coarse material in the upper part of the river is being constantly ground and worn to pieces as it is rolled downstream, so that the size of individual bowlders or cobbles constantly decreases until they finally disappear as such, and the amount of finer material produced by the grinding to pieces of the coarse material increases down the river in just the same proportion as the cobbles decrease. The increase and decrease are correlative. The average velocity of the stream is greater in the upper part of the river, and hence in many places only gravel and cobbles can lodge and accumulate; on the lower river, with its gentler current, sand and silt are characteristic accumulations, and sand and gravel bars are more numerous than on the upper river.

In some places the gravel becomes firmly cemented by limonite, which is probably continually carried along in the river as a flocculent precipitate. It is not known how rapidly this limonitic cement is deposited. Where the gravel remains loose the current may be strong enough at ordinary stages to roll it along the bottom. During floods not only the sand and gravel of the river bottom are in active motion downstream but even the loose bowlders on the upper river may at certain flood stages be heard pounding and grinding on one another as they are rolled along by the strong current. During such stages the bedrock underlying the sand and gravel on the bottom of the river is doubtless scoured bare and subjected to active corrasion.

From Knoxville, Tenn., to Riverton, Ala., the banks of the river are generally stable. Undercutting and caving are noticeable at only a few places, and at none of these is it of serious proportions. This is undoubtedly due in large measure to the fact that the bottom of the river through most of this distance is in solid rock, though the actual bedrock surface is covered almost everywhere by loose sand and gravel, generally several feet and in some places

20 feet or more thick. No very rapid undercutting and lateral shifting are possible where a stream channel is cut into hard rock.

Below Riverton, Ala., the banks of the river are undercutting and caving in many places. This lack of stability throughout the lower section of the river is due to the character of the alluvial materials of which the banks are formed and the decreased slope of the river, which renders easier the accumulation of deposits of sand and gravel in the channel. These deposits deflect the current and cause undercutting of the banks and a tendency to the development of meander curves.

The bed and banks of the river below Riverton are mainly of clay, but hard rocks are found in a few places along the river even down nearly to Paducah, and these rocks are usually scoured bare at certain stages, so that it is certain that through its entire length the river is actively eroding its bed. This erosion, however, is concomitant with the deposition of loose material at many places along the river, for most of the active erosion of the river bed occurs during the rising stages of floods and most of the deposition takes place during the succeeding slack-water stage, at the crest, and during the decline of the flood, when the decreased velocity forces the stream to drop a large part of its load. This process is known as scour-and-fill.

From Riverton to Paducah the current is gentler than on the middle and upper stretches of the river and the deposition has consequently been more rapid, so that island growth and bar formation have been more pronounced and have caused more changes here than elsewhere. Bars have grown into islands and islands have grown until they have lost all semblance of their former selves. This growth has been accomplished mainly by increase in length at the upper ends of the islands and by increase in width. These changes have forced the current against the banks on the sides of the river and have caused undercutting and caving in places. Both the caving and the shifting of the position of the channel necessitate changes in the position of the range lights.

In this lower section of the river the large cobbles of the upper section are unknown; the materials carried are small well-rounded chert gravel and sand and silt, the latter in large amounts.

In the middle section of the river, from Chattanooga down to Riverton, the gravel particles are noticeably smaller than in the section above Chattanooga and are more easily moved. During floods the gravel deposits in this part of the river seem to change more rapidly than those on the upper section. This change may be merely one of form or it may involve change of volume. Practically all the gravel in this middle section is composed of chert and has been derived in part from the long, narrow cherty mountain ridges in the great valley of east Tennessee and in part from the cherty limestones in the region below Chattanooga.

The crystalline and metamorphic rocks carried by the headwater streams from the North Carolina mountains have been ground into finer and finer particles as they have worked down the river until in this middle stretch they have disappeared as cobbles and gravels, but are present in equal volume as sands and silts. An unusually large amount of fine material seems to be produced by the river as it cuts through the mountains below Chattanooga. In the next 50 to 100 miles much of this silt is deposited and has become a very prominent constituent of the islands and bars.

It seems beyond question that deposition in the channel of the river is more active to-day than it was 50 years ago. Wherever it has occurred there is almost always evidence that it has either been recent, or, if long continued, has been more rapid in recent than in former years. Such changes can be attributed only to the great changes that are occurring on the mountain headwaters of the river in consequence of which much greater amounts of sediment are now being furnished to it than ever before. Although in working downstream this material is constantly being ground finer, the fine equivalents of the coarse torrent material are overloading and choking the middle and lower part of the river, and year by year are undoubtedly making the maintenance of navigable channels more difficult. There is a general tendency toward shoaling on bars, and in certain areas channels dredged across them quickly fill up again and

have to be repeatedly reopened. A number of new bars have formed in recent years and some of them have already become serious obstacles to navigation.

In harmony with these findings are the statements made both orally and in their public reports by members of the Army Engineer Corps engaged in improvements on the various parts of the river. Brief references to a few of the more salient features of these annual reports may aid in giving an understanding of the conditions that prevail on the river.

Early reports of Army engineers describe the upper Tennessee River as free from sediment, as of unusually stable bed and banks, and as admirably suited to improvement by open-channel work, consisting principally of blasting out rock ledges, building longitudinal training walls, and closing side channels around islands by dams. In the report made in 1830 by Lieut. Col. S. H. Long almost nothing is said of any necessity for gravel excavation, and even in the report of the detailed examination of the river above Chattanooga made in 1893 the project for obtaining a 3-foot channel includes only $20,000 worth of dredging in a total estimated cost of $650,000, of which much the larger part was to be expended in building dams.

Although gravel bars had always existed on the upper river, they had probably long been stable in form, but these bars evidently began to grow larger in the nineties of the last century and soon caused trouble, for in the Army engineers' report for 1897 it is said that the construction of wing dams and training walls on the upper river has almost invariably been followed by the formation near their ends of bars that may be more troublesome than the original obstruction, that the effects of dredging through these bars of recent formation is likely to be temporary, and that the resulting benefits are soon lost. This is a new note and is in decided contrast to assurances previously given and frequently repeated—that the river was admirably suited to the system of open-channel walls and dams that had been adopted and followed for years.

The succeeding annual report of the Army engineers for some years give evidence of a growing necessity for dredging, and in 1900 the officers in charge of the work deemed it desirable to buy a dredging plant for this upper section. Accordingly a dredge was bought and used, and although, for lack of appropriation, no work was done in 1901 and 1902, it became necessary to rebuild this dredge in 1907 at the Muscle Shoals shipyard, because "it had begun to show too much weakness to continue the heavy digging on which it was engaged in the upper river." In the report for 1907 the doubt that had been raised 10 years before as to the practicability of improving the river by the plan adopted is further strengthened by the statement that there is some question whether the river above Chattanooga can ever be satisfactorily improved by regulation. The statement made in recent reports that the Tennessee is a sediment-bearing river is also in contrast to the old description of it as nonsediment bearing. Rather than to assume that the many Army engineers who had previously decided that this upper section was admirably fitted for open-channel improvement were all so entirely mistaken in their conclusions, it would seem more reasonable—especially in the light of the recognized change in the character of the river—to attribute the failure of open-channel work to a change of regimen.

The survey from Scott Point to Lock A includes most of the open-channel portion of the middle section of the river from Chattanooga to Riverton. The bottom profiles of the 159 miles in this stretch show that of the portions having a depth of less than 5 feet at mean low water 81,850 linear feet, measured along the channel, have a gravel bottom, 77,800 feet have gravel and rock bottom, and 27,900 feet have rock bottom. Between Guntersville and Hobbs Island shoaling constantly occurs on a number of bars, from which over 200,000 cubic yards of gravel have been dredged in recent years. Bars are constantly forming in the open river at the entrance to the upper end of the Elk River Canal and of the Muscle Shoals Canal, and regular dredging is required to keep the entrance to the canals open.

On the lower river, from Riverton to Paducah, because of the decreased fall, there is more opportunity for sand and gravel to lodge. The survey of 1896 showed 49 bars, all but two or three composed of gravel. It was calculated that the removal of 650,000 cubic yards of sand

and gravel would be sufficient to open a channel across these 49 bars. Channels were dredged through a number of them, only to fill up at the next season of high water. One has been opened five times in 8 years. In a few years it has been necessary to remove from certain bars several times as much material as was originally calculated. For example, the calculated amount of gravel dredging required at Big Chain bar was 16,716 cubic yards, but 66,345 have been removed. At Rockport bar 13,321 cubic yards needed removal; 80,262 have been removed. At Beech Creek Island the calculation was 34,948 cubic yards; 174,500 cubic yards have been removed. Moreover, several new bars have developed since 1896, and have interfered with navigation so seriously that it has been necessary to dredge them before certain of the older bars had even been touched. The Army engineer in charge sums up general conditions on this lower part of the river by saying in the report for 1908 that in 1896 it contained 49 shoals, and that several others have since been formed; that 1,127,660 cubic yards of gravel had been dredged at 31 localities, and that the results were fairly permanent at two-thirds of the places.

These brief abstracts from the reports of the Army engineers indicate that, though permanent improvements on the Tennessee may be made by building locks and dams, such as those at Muscle Shoals and elsewhere, and by blasting rock ledges from the channel, the improvement resulting from building training walls is of uncertain value, and that the improvement by dredging is in many places only temporary, the benefit being soon lost. This conclusion does not imply that it may be wise not to dredge at all, but rather that, however wisely planned and faithfully performed, the task of improving a river like the Tennessee, under the conditions of erosion and silting that now exist in its basin, is never ending, and that dredging will always be necessary to maintain an open channel as long as present conditions on its headwater tributaries prevail. A single sand bar may effectually block the river and render useless the locks and dams, nullifying the results of the expenditure of millions of dollars for their construction. To what extent these conditions would be improved by extensive reforestation of the steep headwater slopes it is impossible to predict, but it is believed, both from the logic of the case and from the contrasted example of such rivers as those of the Coosa-Alabama system, that the benefit would be material, and either alone or in connection with other benefits flowing from such a policy would be well worth the necessary outlay.

It is to be regretted that no thorough examination and survey of the river was made long enough ago to enable a more detailed comparison of previous conditions to be made with the conditions found to-day. Most old examinations were made where rock ledges reach near the river surface or where gravel bars had already grown so near the surface that the current prevented much further growth; and in many areas changes that would have naturally occurred at critical points have been prevented or masked by dredging and the building of rock training walls during the improvement of the river. Places where no efforts at improvement have been made usually afford the best opportunity to observe the natural changes that are occurring in the river. It is chiefly such places that are described in detail in the following pages.

It is recognized that any individual bit of evidence may be misleading, but when innumerable bits, gathered from many sources and varying greatly in kind, harmonize and point to the same general conclusion, it is difficult to believe that conditions are in reality just the opposite of what they seem to be. The conclusion is irresistible that the evidence is an accurate index of the facts and may be accepted as trustworthy. In presenting this detailed evidence of change along the Tennessee the river will be considered in three sections—an upper section from Knoxville to Chattanooga, Tenn.; a middle section, from Chattanooga, Tenn., to Riverton, Ala.; and a lower section from Riverton, Ala., to Paducah, Ky.

DETAILS OF CONDITIONS.

FROM KNOXVILLE TO CHATTANOOGA.

The first point below Knoxville at which changes were observed was Lyons Shoals. The main or right-hand channel is said to be shallow enough to permit horses to ford across to the island from May until late in fall; years ago it was necessary to ferry them during the crop-

working part of the summer, and only late in fall did the river get low enough to ford. Either ordinary stages of the river must now be lower there during the summer than formerly or the channel must have filled considerably with gravel; the latter seems more probable. Army engineers report that the channel is shoaling and that a bar of gravel is forming at the lower end of their dam. The two main islands are being tied together by the filling of the channel between them. At low water this chute now becomes dry.

At Williams Islands the upper and middle islands are being extended by a deposit of gravel on their upstream ends; the lower island seems to be stationary. Army engineers report that the right chute, which is the steamboat channel, is shoaling with gravel.

At Little River Island the dams built for the improvement of navigation have so changed the currents that though both cutting and filling are going on it is impossible to say which process dominates.

At Post Oak the two islands will before long be united by the gravel bar forming in the channel between them. The right-hand channel is also filling.

At Prater Island cutting is in progress on the upper end and filling on the lower. The channel on the left side is filling and now goes dry during the summer and fall. Before long these islands will be tied to the left bank and the entire current will pass down what is at present the right-hand channel.

On Cox Island the timber protecting the upper end has been cut away and this end has been especially damaged by floods that have swept across the island. The bar at the head of the island seems to be growing slowly.

Russel Shoals show an accumulation of gravel on the bar, shoaling in the channel below the dam, and a shifting of the position of the channel as compared with its condition in former years.

Roger Islands show a slow growth upstream, and above the upper end of the larger island a shallow gravel bar is forming—a feature that is generally characteristic of other islands in this part of the river. The right-hand side of the islands seems to be growing by the deposition of gravel and silt and is pushing the river channel farther to the right.

The upper end of Chota Island is protected by a rock dam, behind which gravel and sand are accumulating and extending down the upper part of the island. Just below Dam No. 2 bars are constantly forming and obstructing the channel on both the right and left sides.

Behind the dam across the upper end of Coulter Islands filling is in progress. The channel between the middle and the lower island is filling, so that these two will soon be united.

At Leipers Ferry the river is reported to have filled considerably in the last 20 or 30 years.

Sister Islands are situated in a relatively straight reach of the river and seem to have reached equilibrium; they are neither visibly growing nor wearing away.

The upper end of the uppermost of Belle Canton Islands shows a recent upstream growth of 100 yards; on the right-hand side there has been a lateral growth of 20 yards, and the steamer channel has been pushed farther to the right. The second of these islands shows a growth of 150 yards on its upper end, but its sides, as well as the lower ends of all three islands, are stationary.

At Lenoir Ferry the river is reported to be lower, as a rule, during the summer and fall than it was 40 or 50 years ago.

At Lenoir Shoals, just below the mouth of Little Tennessee River, navigation of the narrow, crooked steamboat channel is rendered still more difficult by an accumulation of gravel, seemingly due to the great amount of material furnished the river by the Little Tennessee.

Rock Quarry Bar is reported to be growing and the channel across it is shallower than formerly.

Carmichael Island seems to be slowly growing upstream, but some 200 yards of its upper end has been badly scoured and much of its soil has been removed by recent floods. This scouring has injured some of the cultivated land on the island and has washed up trees, 6 to 10 inches in diameter, that formerly protected the head of the island from erosion.

At the upper end of Loudon Island four small towheads that appeared years ago have been growing until they will shortly unite with one another and with the island below them. The upper ends and the sides of the islands were already growing slowly when their owner began to aid their growth by cutting the willows around their edges so that, though their gain in area has been notable in recent years, it is not a fair index to the natural rate of growth. It shows, however, that only slight encouragement is needed to cause sediment to lodge at any point, so great is the amount carried by the river.

Harrison Island and two towheads above it have, by the filling of the channel to the left of them, been united to the left bank of the river. This process has been aided by the owner, although it was started by the stream itself.

Sweetwater Island is protected above by a rock dam behind which gravel has lodged in large quantities during recent years. The sides and lower end of the island seem stationary. Halfway between Sweetwater Island and Bogart Island, near the left bank of the river, a recently accumulated gravel bar, some 25 yards long at ordinary stages, has deflected the boat channel to the right. At the upper end of Bogart Island a towhead is growing and a gravel bar is filling out to the left of it. The two main islands are being tied together by the filling of the channel between them.

An uncharted gravel bar, which probably had recently formed, was observed near the right bank just below Marble Bluff Landing.

Wilson Island is stationary except at the upper end, where a gravel and cobble deposit is forming behind a dam.

At Seven Islands a towhead has appeared above the upper island and become attached to it by a deposit of gravel and the channel between the two islands is closing. In the same way the lower end of Long Island is being extended downstream by the deposition of fine silt. Deposits of sand and gravel are forming about the dams that unite the upper end of Round Island to the left bank of the river. The upper end of Long Island itself is growing, and on the right side, just below the shoulder which deflects the main current to the right, two small towheads have formed and are becoming attached to the island.

Just above the mouth of Clinch River the right bank of the river is being undercut, and undercutting was noted on the same side some 4 miles farther down, just below Hoods Ferry. The amount of the cutting, however, is slight and it is mentioned merely because the banks, as a rule, show little or no signs of such change.

At Pickles Bar the recent accumulation of gravel is said to have greatly changed the steamboat channel and rendered it more difficult to follow.

Kings Bar is also reported to be shoaling.

Just below Rockwood landing Bracket Bar has shoaled so much in recent years that it has been necessary to cut and buoy the channel through it. It is not described in any report previous to 1893 and is evidently of recent formation. In 1904 about 29,000 cubic yards of sand and gravel were removed. The distance dredged was 2,100 feet.

The upper end of Halfmoon Island is being undercut by the current, which sets strongly against it. Back of the rock dam that deflects the current to the left, however, a deposit now forming is uniting the main island to the two small islands above it.

At Whites Creek Islands in the last few years much gravel and silt have been deposited on the main island and the several towheads above it. One of the towheads has recently grown into a fertile island, which was patented from the State of Tennessee by one man and claimed by another on the ground of riparian right, and thus became the cause of personal strife and later of lawsuits between the claimants. Gravel bars are also forming in Whites Creek Shoals in spite of the long dam built to improve them. A bar persistently forms below the end of the dam, although the dam has been repeatedly extended in order to prevent such accumulation.

At Preston Island a towhead, formed in recent years to the right of the head of the island, has grown so rapidly that it is now 250 yards long, rises 10 feet above low-water level and has willows 20 feet high growing on it.

At Euchee the left bank is 45 feet high and the undulating, irregular flood plain is covered only at long intervals and by floods of extreme height. A mile back from the river, however, there is a lower sluice across which floods ordinarily run and have done much damage.

Piney Island shows a relatively rapid growth upstream. The main body of the island rises 20 feet above water level and is protected by well-grown trees. Above it there is a crescentic sloping belt, which extends 150 yards upstream and above this a still lower belt 250 yards broad, reaching down to water level. Beneath water level there is a gravel bar that may be traced for some distance upstream and is undoubtedly growing.

Behind the dam that protects its upper end Watts Island is growing by the deposition of abundant flood-borne detritus.

Hunter Island is now almost tied to the left bank by the filling of the intervening channel. The upper end is growing slightly. The gravel bar opposite this island is 4,000 feet long.

Just below the middle of Good Field Shoals a gravel bar has accumulated near the left bank in recent years, and now rises considerably above ordinary water level.

Across Martin Bar the deflection of the channel is reported to be decreasing, owing to an accumulation of gravel now in progress. This bar was 1,000 feet long in 1893 but had not previously been described.

At the mouth of Hiwassee River the upper island is slowly growing upstream, and on its right side towheads are forming and uniting with it, so that the current is deflected to the right and the main channel is slowly shifting in that direction.

Above the upper end of Upper Sale Creek Island a large gravel bar has been formed, and a towhead 300 yards in length is forming and has almost joined the island. On the lower island a similar large gravel bar and towhead have been developed, and the main channel is reported by Army engineers and others to be growing shallower by constant accumulation of gravel.

Soddy Islands are growing on both their upper and their lower ends, but as these ends are connected by longitudinal dams it is uncertain whether the entire growth may not possibly be due to the influence of the dams. It is practically certain that the accumulation of débris so generally noted about dams is in general due to their influence in checking or producing eddies in the current.

Dallas Island was washed badly in 1876 but has grown somewhat since then on the upper end. The channel is shoaled by a gravel bar that has accumulated at the head of the island.

An octogenarian at Harrison Landing reported that the flood of 1867 was the highest within his memory, and that that of 1876 was the next highest. Floods during recent years, in his opinion, have been more numerous than formerly. He also stated that low water in summer and fall in olden times was lower than to-day. This was the only statement of the kind heard on the river, but the opposite observation and belief was reported by many persons.

Chickamauga Island shows a slow growth on the upper end. Just below this end there is during floods active deposition of sand and gravel, which are dug as building material for Chattanooga markets. The pits dug out during low water rapidly fill again during floods, so that the supply perpetually renews itself. In the last few years a gravel and sand bar has grown several hundred yards from the upper end of some small islands just below and to the right of Chickamauga Island.

At Colwell Bar there is a gravel deposit that is growing upstream, and just below it gravel bars have formed on the right, deflecting the main stream channel sharply to the left. The gravel bar here is 4,000 feet long.

FROM CHATTANOOGA TO RIVERTON.

The stretch of river between Chattanooga, Tenn., and Riverton, Ala., is 238 miles long and may be conveniently divided into three parts. The upper part is 17½ miles long; in this stretch the river cuts through the mountains just below Chattanooga and has a fall of 27.9 feet, or an average of 1.9 feet per mile. The current in this part is generally swift. In some places where the stream is sawing its way down through hard sandstones it is much contracted in width.

Rock débris entering this mountain stretch has little opportunity to lodge anywhere but is swept along with impetuous force and is well ground to pieces before it enters the succeeding stretch. The middle stretch extends 158.3 miles, to the head of Muscle Shoals Canal, falling in this distance 63.8 feet, or an average of 0.4 foot per mile. In this stretch the current is gentler, and in it much of the silt ground down by the river on its way through its mountainous stretch finds lodgment and is building bars and islands. In the third part, which extends from the head of Muscle Shoals 61.5 miles to Riverton, the fall is 168.5 feet, or 2.73 feet per mile. In this stretch are included Big and Little Muscle shoals and Colbert Shoals.

The first deposit of sand and gravel in the river below the Chattanooga wharf is at Ross's towhead, where there are sand and gravel pits from which material is dug for Chattanooga markets. These pits fill quickly during floods and the supply is consequently inexhaustible. The towhead does not seem to be materially growing or wasting. The chute to the left of the towhead was originally selected as a boat channel and was improved, but it was so difficult to keep open because of the constant accumulation of sand and gravel in it that in 1894 the Army engineers abandoned it and began blasting a new channel near the right bank.

Williams Island, 6 miles below Chattanooga, is not changing in any manner.

The Skillet towhead is composed of sand and gravel and seems to be in stable condition, as is also Savannah towhead, some miles below.

Burns Island, in the middle stretch as here defined, may be wasting slightly on its upper left side, but the lower end has grown 100 to 125 yards downstream in the last six or eight years, and its height has been so greatly increased by deposits during floods that the lower branches of the old trees are now being buried by the sand and silt.

Bridgeport Island is not changing in form, but the upper end is growing higher by the deposition of silt.

Crowtown Island shows an unchanged outline but is becoming higher on the upper end. Above it there is a well-developed gravel bar, which seems to be stationary.

The sides of Bellefonte Island are stationary but the upper end has grown some 50 yards in the last five years and the lower end is becoming higher and is extending slowly down the river. The deposit on the lower end is very fine silt. The bar just below the island is shoaling, and at low water several acres of sand and gravel are now exposed.

Thirty years ago Larkin's towhead was above water only at long intervals, at exceedingly low stages of the river; 22 years ago it is reported to have been 150 to 200 yards long; now it is over 500 yards long and is cultivated in corn. Its growth has been more rapid within recent years than formerly.

At Ferry's landing, on the right side, 100 to 125 feet above present river level, there is an old river terrace whose gravels and pebbles are very similar to gravel deposits found in West Tennessee, and they may be of the same age.

Across the upper part of Pine Island a runway formed in the great flood of 1867, cutting off the upper end of the island. Since then this runway has filled up and the island has grown upstream 150 yards. The lower end is growing higher by the deposition of silt and has recently grown some 50 yards farther downstream.

The upper end of Buck Island is growing in height and has extended upstream 150 yards in the last 10 years. The sides and lower end are stationary.

The towhead above McKee Island is said to be growing, but Henry Island and McKee Island are not changing.

Flint River towhead is reported unchanged and Byrds Island has changed very little. The lower end of the island has extended downstream some 30 yards in the last 17 years, but the upper end is wasting somewhat. The area of the island 100 years ago was 324 acres and is approximately the same to-day.

From Lock A to Florence so many artificial changes have been made by dredging channels and building locks and dams around Big and Little Muscle shoals that it is impossible to draw any important conclusions as to the natural changes. Bars are forming in the open

river at the upper entrances of both the Elk River and the Big Muscle Shoals canals and require the almost constant use of a dredge to keep the channel clear.

Sevenmile and Big Buck islands are probably stationary. On their bars there are large deposits of well-rounded chert gravel, and though this gravel is constantly changing from flood to flood the bars themselves seem to be neither wasting nor growing. Halfway down the side of Big Buck Island, however, there is a towhead above which a gravel bar has grown since the Government dam was built in 1878, and below it another towhead has formed in the last 15 or 20 years and is steadily growing.

Little Buck Island is actively growing. There are bare gravel areas at its upper and lower ends.

Coker Island is almost tied to the right bank by the filling of the channel on that side; otherwise it has not changed.

Just above Bee Tree Shoals a towhead 175 yards long, near the right bank, has within recent years grown about 50 yards.

FROM RIVERTON TO PADUCAH.

Riverton is 426 miles below the head of the river just above Knoxville and 226 miles above the mouth at Paducah. The fall in this lower portion of the river is 78.5 feet or 0.34 foot per mile. The obstructions in this section are practically all sand and gravel bars.

At Bear Creek Shoals gravel is accumulating on the left side near the lower end of the shoals and is forcing the current against the right bank, which is being undercut near the Government light. The banks here are 30 to 35 feet high, the lower 10 feet being of yellow chert gravel and the upper part of clay; caving is relatively rapid. The current is deflected from this bank to the opposite side of the river and has begun undercutting at Paynes Landing just below, and this swinging when once started tends to become more pronounced and to develop additional meander curves farther downstream. It will soon cause material changes in the boat channel.

At Shaws Landing the right bank for 500 yards is scouring away and caving. The material is a gravel overlain by clay.

State Line Island is growing higher by deposit of fine sediment and is extending upstream. The change is reported to be much more rapid in the last few years than formerly, and the bar at the head of the island is extending out into the channel farther than it did. The lower end of the island seems to be growing slowly downstream, while the chute to the left is filling up, so that the island will ultimately be tied to the left bank of the river.

At Pittsburg, Crump, and Coffee landings, all of which are on the left bank of the river, there are bluffs of relatively soft sands and clays that are being undercut, and the banks are caving at such a rate as to interfere materially with the maintenance of the boat landing.

A bar at the upper end of Diamond Island has grown 200 or 300 yards in the last 15 years. During this time a bar has formed to the left of the head of the island and has grown to it and extended down the left side of the island. It is deflecting the current to the left bank of the river and is now causing undercutting and caving. Below this bar a gravel fringe has grown along the side of the island to within 300 yards of the lower end; this fringe is 2 to 5 rods wide and is evidently growing. By the survey of 1896 it was calculated that this bar could be improved by dredging 8,000 cubic yards of sand and gravel; in 1901 the amount dredged was 19,500 cubic yards.

Wolf Island, at Crump Landing, has been formed by the union of two islands that existed there in 1865, as is shown by a map published in that year. Since then it has been growing upstream, and on the left side the gravel fringe has widened so much that the main current has been deflected against the opposite bank and is undercutting it just below the landing. A small gravel towhead that was just visible at low water 30 years ago now covers several acres. Dredges removed 37,800 cubic yards of gravel from the channel here in 1901.

Petticoat Bar has only in recent years begun to be regarded as a serious obstacle to navigation, but in 1908 it became necessary to dredge a channel a distance of 1,900 feet across it.

Swallow Bluff Island has been united by a gravel and sand bar to a smaller islet and a towhead above it and to the right. The bar is growing slowly, but the towhead has grown much larger than it was 25 years ago. The chute on the right is reported to be filling up.

Below Indian Creek a gravel bar is forming on the right bank. This bar is reported to extend much farther out into the river now than formerly. Below it, on the west side, another bar is also growing.

Eagle Nest Island is now filling slowly on its upper end and in the last 15 years a gravel spit has been building along its left side. The deposites of silt are building the island higher yearly, while the river current deflected by the deposit of gravel on the side of the island is undercutting its left bank. This island, shown on the 1865 map as only about half a mile long, is now 1½ miles long.

Roches Bar is said to be shoaling and extending farther upstream, so that boats have more trouble than formerly in making the landing on the west bank. This bar was not indicated at all on the map of 1865.

Kirkpatricks Island is steadily growing on the west side and the upper end and the chute to the right is filling up. In 1865 the island was insignificant. To-day it is over a half mile long.

Beech Creek Island has grown greatly since 1865, but its upper end is being eroded by a cross channel. Its lower end is growing, and the former steamboat channel between it and Culps Island, just below, is now practically dry at low water, and in a few more years these two islands will be united. The channel dredged in 1900 filled the following season and has had to be redredged. From the survey of 1896 it was calculated that improvement would require 35,000 cubic yards of gravel to be removed. In 1900 65,000 cubic yards were dredged, and in 1902 109,000 more.

The smaller of the Double Islands is cutting away on its right side along the lower third of its length, while from the upper end of the larger one a sand bar is growing downstream on the right side, deflecting the current of the river to the right and undercutting the right bank. These islands seem to have grown notably since 1865.

Kelleys Island has not changed in the last 15 years, but the bar near the lower end has been growing, and within recent years boats have had to keep much nearer the shore to avoid it.

The sand bar opposite Cedar Creek, just below the narrows, has not changed in the last 15 or 20 years; but the sand bar on the right side of the upper end of Densons Island is growing and pushing the steamer channel to the right and causing the right bank of the river to undercut and cave.

Just below the mouth of Duck River there is on both sides of Tennessee River a large deposit of sand and gravel, most of which has been brought down by Duck River. This deposit is apparently slowly growing.

Rockport Island is nearly stationary; the lower end may be growing slightly. The chute to the left is becoming shallower. The channel across Rockport Bar persistently closes after being opened. It has been opened five times in eight years and will probably continue to close with each year's spring floods. Each reopening requires on the average over 20,000 cubic yards of sand and gravel to be dredged.

A bar at Duck River Suck is shoaling and pushing the current against the west bank. In 40 years this bank has caved some 400 feet. Most of this erosion has occurred within the last 10 or 15 years, in which time the river here has engulfed a house and an orchard.

At Johnsonville a gravel bar, which now shows some 10 acres at low water, has grown since 1865, and is causing the left bank of the river to undercut. It is filling the steamboat channel, and has already required the dredging of 110,000 cubic yards of sand and gravel.

To the left side of the upper end of Reynoldsburg Island a gravel bar is growing downstream and extending to the left, pushing the river current against the left bank and causing caving. It was less than a mile long in 1865 but is now 1½ miles long.

Turkey Creek Island is not changing.

White Oak Island is reported to have grown 200 yards on its upper end in the last five years; a bar on its upper end is crowding the main current to the left, and the right-hand chute is shoaling.

The channel between the two Hurricane Islands is filling and also narrowing by the growth of a bar that will soon unite them into one.

On Leatherwood Shoals the bar on the right side is said to be growing and the chute on the left closing. The channel across the bar has recently required dredging.

Panther Creek Island is reported to have grown considerably since it was patented in 1870. In 1904 the bar gave much trouble and required extensive dredging.

Blood River Island is growing on both its upper and lower ends, and the channel to the left has shoaled so rapidly that it is now completely dry in low water.

Pentecost Towhead is slowly growing on its upper end.

Birmingham Island has not changed in the last 40 years, but a bar just below it has grown from 2 to 10 acres at low-water stages during this time.

Threemile Island has extensive gravel bars at both its head and its foot, and the channels dredged through them have refilled and required redredging. Over 140,000 cubic yards of sand and gravel have been removed.

Sevenmile Island is said by an old resident not to have changed in the last 40 years, and its entire outline seemed to be in stable condition.

The towhead just above Tennessee Island at the mouth of the river seems to be growing slightly, though Tennessee Island itself has not materially changed within recent years.

COOSA-ALABAMA RIVER SYSTEM.

The headwaters of the Coosa-Alabama River system—Oostanaula and Etowah rivers—rise in the mountains of northern Georgia and northeastern Alabama and unite at Rome, Ga., to form the Coosa, which in its lower course becomes the Alabama and flows southward and westward into the Gulf of Mexico near Mobile. A detailed examination was made of the headwaters of this system in northern Georgia, and the Coosa was traversed by steamer from Rome, Ga., 165 miles, to Gadsden, Ala. Below Gadsden conditions along the river were studied at several points, the lowest of which was Selma, Ala.

OOSTANAULA BASIN.

COHUTTA MOUNTAIN REGION.

The main mass of the Cohutta Mountains is in northwestern Georgia, some miles southwest of Ducktown, Tenn., but the mountains extend northward into Tennessee, where they are deeply trenched by the gorge of Ocoee River. Most of this mountain area, however, drains into the Coosa system. The rocks are ancient granites, gneisses, schists, and slates, which have been greatly weathered and eroded. The mountain mass is deeply cut by numerous streams, which flow from it in a somewhat radial fashion. The ridges are sharp topped and steep sided; the intervening valleys are narrow and most of them contain only the merest traces of a flood plain. The highest parts of the mountains are between 4,000 and 4,500 feet in elevation. The land is poor as a rule, and very little of it is cleared for agriculture. Most of the timber has been purchased by lumbermen and is being cut wherever transportation is possible.

The entire basin of Jacks River is wooded, with the exception of its upper 2 miles. It was being actively lumbered when examined, but showed no material erosion as a result of lumbering. At its very head the slopes have been cleared to a considerable extent and some of the fields are old and have become badly gullied. The total cleared area in the basin, however, is less than 2 per cent. The west side of the basin has been logged down to Cowpen Mountains, but the country farther down is in original forest. The soil is so poor that in some places it is reported that lumbermen have abandoned their holdings after they have cut them over.

South of Sassafras Gap, at the head of Mountaintown Creek, the entire country is wooded for several miles; then a flood plain begins to appear along the small creek and soon becomes a third of a mile wide. It is cultivated in places, as are also the lower slopes on either side. These lands do not show erosion or damage by floods.

The small headwater tributaries of Mountaintown Creek are bordered by narrow flood plains of moderate fertility, most of which are cleared and in good condition, and some of the lower slopes are also cultivated. There seems to be no marked erosion in this basin.

The basin of Holly Creek is wooded from its head to the point where the stream leaves the mountains, some 5 miles downstream. Below this point the creek has formed a flood plain which is at first beveled or sloping and is almost entirely above the reach of floods, but within a few miles becomes more nearly level and extends continuously down to the mouth of the creek. During floods the upper 10 miles of this flood plain receives deposits that enrich it; the lower 10 miles is not so fertile, lies lower, and is in places swampy. It is not damaged anywhere by floods.

CONASAUGA RIVER.

Above Treadwell, Ga., Conasauga River has a fertile flood plain that ranges in width from half a mile to 1½ miles. The grade of the river is low and its velocity during floods is not great enough to seriously injure the lands by erosion.

The bottoms below Treadwell are neither so broad nor so fertile as those above, but both are uninjured. The flow of the stream seems rather constant. The owner of the mill at Treadwell reports that only a few times during the last 20 years has it been necessary to shut down for want of water. This freedom from flood damages and regularity of flow are undoubtedly due to the forest protection on its headwaters.

Conasauga River unites just above Resaca with the Coosawattee to form the Oostanaula. The Oostanaula meanders irregularly across a flood plain that is perhaps half a mile in average width and on either side is bordered alternately by bluffs and flood-plain areas. Its bottoms are not greatly damaged by floods, it is navigable throughout its entire course, and it contains no bars or islands that seem to be growing.

COOSAWATTEE RIVER.

The Coosawattee is navigable to Carters, at the foot of the mountains. The width of its flood plain varies greatly, but averages from one-fourth to one-half mile, though in a few places it is a mile or more. The ordinary flood plain of the stream is bordered in many places by an extraordinary one, 10 to 20 feet higher, and rounded stream gravels are found on the valley sides 50 to 60 feet above present flood-plain level. The highest flood recorded occurred in 1866, when some places were so badly washed that they have only just about made back again. In some localities to-day ordinary floods erode the bottoms and do considerable damage, but the farmers along the river generally regard floods as beneficial, rather than harmful, because of the sediment they deposit. This deposition of rich sediment is especially marked at Carters, where the mountain stretch of the stream, which has a high gradient, runs out upon a broad plain and assumes a low gradient and at once begins to build a flood plain.

From Carters southeastward to Silver only the lower slopes of the bordering uplands are cleared and along the streams there are narrow bottoms, most of which are also in cultivation. Some of the older hillside clearings have become badly washed.

On Talking Rock Creek, west of Blaine, 50 or 60 per cent of the uplands have been cleared and some 10 per cent of them show extensive erosion. East of Blaine about 30 per cent of the uplands are cleared and there is but little erosion. At Talking Rock Station there is a broad flood plain bordered by a fossil one 15 feet higher, whose back part rises gently upward to the tops of the low hills. These hill slopes are in places largely cleared, but the cleared areas, upland and bottom alike, are generally in good condition. Farther east, at the heads of Fishing and Price creeks, the lands are very poor and the clearings are confined to the very lowest slopes of the valley sides and the narrow bottoms along the streams. Perhaps not more than 10 per cent of the entire area of these stream basins is cleared.

In and just west of the gap at the head of Clear Creek there are numerous old fields, most of which have been worn thin and abandoned, but only here and there are there signs of marked erosion. Northeast, east, and southeast of the gap the entire region is forested except in two small areas, one covering a few acres, the other a few score acres.

ETOWAH RIVER BASIN.

Etowah River heads on the southern slopes of the Blue Ridge northwest of Dahlonega and after flowing southward 25 miles turns to the southwest and unites with the Oostanaula at Rome to form the Coosa. Its headwater region is largely uncleared except for narrow flood-plain areas and an occasional low valley slope.

No clearings were seen west of Amicalola Creek, but along that stream some bottoms 200 or 300 yards wide have been cleared and are in good condition.

From Amicalola Creek eastward to Etowah River the soil of the rolling to hilly uplands is generally poor and practically all the land is wooded. Along the many small streams in this region there are some narrow flood plains, most of which have been cleared and are uninjured by floods. Some small areas of the bordering slopes have also been cleared, but much the larger part of the region is in forest and is not eroding.

Etowah River is shallow and swift, with steep banks 12 to 15 feet high. It has a level sandy flood plain of moderate fertility, bordered by a flat-topped terrace 15 feet high. East of the river is an old, flat, cobble-strewn terrace that stands 80 feet above the present flood plain.

In some parts of its course the rocks are more resistant and it flows in a narrow gorge without a flood plain. Throughout the greater part of its length, however, it winds irregularly, and on one side or the other has developed a flood plain that in places may be half a mile or more in width. During floods it carries a large quantity of sand and gravel, a considerable part of which is due to hydraulic mining on the uplands, but a part of which is due to dredging operations which are carried on extensively along the river near Auraria and Landrum.

In many places the Etowah has a very narrow ordinary flood plain, 6 or 8 feet above water level and 1 or 2 rods wide; above this there is an extraordinary flood plain with undulating surface 12 or 15 feet higher and of varying width, but in places as much as 200 to 400 yards wide, especially on the concave side of incised meander curves. In a few places this extraordinary flood plain is half a mile or more wide. Both the ordinary and extraordinary flood plains are generally formed of a sandy loam and rarely show great damage by floods. In many places there is also a well-developed fossil flood plain or terrace 20 or 30 feet above the present extraordinary flood-plain level.

From Landrum down to Canton flood-plain areas have not been seriously injured by floods. At Canton the ordinary flood plain is 300 yards wide, stands about 15 feet above stream level, and is quite flat. It shows slight erosion from floods. The extraordinary flood plain is not well developed just at this point, but may be seen both above and below.

Just west of Field's bridge, on the north side of the river, there is a good example of the flood-plain topography found in so many places along this river. From the northern valley wall an old beveled fossil flood plain, produced while the river was cutting down and swinging southward, slopes to the south with a very gentle grade. It is about half a mile wide and at its lower edge there is a descent of 8 to 12 feet by a well-defined scarp to the present flood plain, which is much more nearly level and also about a half mile wide.

This last or living flood plain has a somewhat undulating surface, produced by the scouring action of the higher floods, which have cut occasional runways, so that it has been necessary to build dikes or low walls to prevent serious erosion. The highest floods cover this bottom to a depth of 12 to 16 feet; the lower or ordinary ones cover it but a few feet. On the south side of the river there is a similar living flood plain at the same height but of less width.

The soil on both the fossil and the living flood plains is fertile and, though the river occasionally injures the lower one by washing, the farmers regard floods as beneficial in

their general results rather than injurious. The greatest injury done by them consists of the destruction of a crop when high water happens during the growing season.

From Canton to Cartersville much of the upland on either side of the river is poor and the larger part is uncleared. In some places the cleared lands have a porous soil and do not erode badly; in others the soil is a more compact clay, and steep slopes that have been long cleared show gullying.

The Etowah for some distance below Canton has an average fall of 2 to 2½ feet a mile—a slope that tends to produce broad flood plains, such as those at Field's bridge.

Two miles below Galt's ferry the river enters a narrow, rock-bound gorge and for 6 miles descends in rapids at the rate of 14⅗ feet a mile. Below these rapids the gradient again decreases to about 2½ feet a mile, and this, which may be called the normal slope of the Etowah, continues for 45 miles, to its mouth at Rome, Ga. Throughout this distance the stream has formed a flood plain that is in many places 200 to 400 yards wide, especially in the upper part of this 45-mile stretch. On concave sides of bends, where the stream cuts across limestone belts, the width may increase to a mile or more; where more resistant rocks occur the hills may close in and practically shut off the flood plain. Width of flood plain is a function of both river gradient and rock resistance.

Immediately below the rapids, where the gradient decreases to the normal again, flood velocities are checked and much sand is deposited, so that for about a mile the bottoms are poor and sandy and show some gouging by floods. Below this they are, as a rule, composed of fertile loam.

Just south of Cartersville broad bottom lands—now very largely fossil—have been developed on a limestone belt. The living flood plain is very narrow here and is fertile and in good condition. Below this limestone belt the hills close in at several places on the river, but at others the valley opens again and there is the usual development of an old, undulating, sloping fossil flood plain, as a rule somewhat irregular, but distinct, and from 8 to 12 feet high. The upper limit of the old beveled flood plain is generally about 60 feet above the present one. This fossil flood plain is above the reach of all floods and its slope is too gentle for serious subaerial erosion. The present flood plain, as a rule, receives deposits of silt during floods and is being built higher and enriched. At bends or where rafts lodge—as at bridges and other obstructions—some holes and flood channels were observed, but these may soon be filled by succeeding floods of less height and velocity of current. The flood of 1886 is the highest reported. It cut across and scoured many bends and in a number of places washed out flood channels that have not yet been filled.

Below Kingston the banks of the river are 20 to 25 feet high and the present flood plain is narrower. In most places it is distinctly separated from the fossil flood plain by an 8 to 12 foot scarp, but locally this scarp is absent and the boundary between the two is indefinite. The surface of the old higher flood plain is very undulating and in many places slopes irregularly upward to an indefinite union with the old high valley wall. On the valley sides are many cultivated tracts. Where the soil is composed of a cherty clay the clearings do not erode greatly, but where the clay is more compact erosion generally begins within 5 or 10 years after clearing and in a few more years the fields are abandoned.

COOSA RIVER FROM ROME, GA., TO GADSDEN, ALA.

The 165 miles of river between Rome and Gadsden were examined from a steamboat that ran only during the day, so that an opportunity was had of examining the Coosa for its entire length. Many landings were made along the way and the passengers and officers on the boat furnished information concerning the condition of the river and the changes that have occurred in recent years.

The banks of the river are generally covered down to the water's edge with trees which effectively protect them from erosion. At only a few places was any undercutting of banks

and caving noted, and at these it was so insignificant in amount and extent as to be negligible. The banks are everywhere very stable.

At and just below Rome the banks are 20 to 25 feet high and very steep, and the flood plain was either narrow or absent. About 30 miles farther down their average height had decreased to 15 or 18 feet and they were still steep and wooded. Still farther downstream the river widened and deepened and the average height of the banks was yet lower, until at Greensport, below Gadsden, they were reported to be only 4 or 5 feet high. There is a corresponding decrease in the height of floods down the river. A stage of 30 feet at Rome, which covers the flood plain, at Greensport makes a stage of only 5 feet, which barely suffices to cover the flood plain. This concomitant decrease in height of flood crest and of flood plain surface down the river is normal and necessary. The flood wave tends to lengthen or flatten out as it advances downstream and thus lowers the height of the flood crest, and since the flood plain is built by the flood it is necessarily limited in elevation by the height of the crest of the floods that produce it.

There are comparatively few gravel bars in this 165 miles of river, and those known are reported by the pilots to be stationary in position and height. Some of them have been dredged in recent years by the Federal Government. The material thrown out on the banks is chiefly well rounded chert gravels and cobbles, most of which are less than 3 inches in diameter, though the large cobbles have a diameter of 12 inches. In some places pieces of blue shale or slate are mixed with the chert. In only a few localities are there any visible gravel accumulations below the mouth of tributary streams, and where such gravel beds occur they seem to have reached points of equilibrium between the forces that built and the forces that destroy them.

The islands in the river are small and most of them are the ordinary midstream islets, but a few others of unusual type were observed, 100 or 200 yards long, 6 or 8 feet high, and only 20 or 30 feet wide. Such islands lie very close to one bank or the other and were covered with trees. Inquiries and personal examination failed to discover that any changes are in progress on such islands. They would seem to have originated by the undercutting of a portion of root-matted river bank until it broke loose, slipped into the river, and became a long, narrow islet, parallel and very close to the bank from which it was derived. If this be the mode of origin the time was remote enough for all trees that may have been tilted when the island was formed to have disappeared, as all now standing are perfectly erect.

At many places the bed of the river contains rock ledges that lie as a rule at sufficient depth to be no serious menace to navigation. In many other places the rock in the bed of the river is covered by a very few feet of loose gravel. The river seems to be eroding its channel.

At 9½ miles and again at 10 miles below Rome there are two gravel bars that have been dredged within the past few years. This dredged channel has not since shown any tendency to fill. The material removed was chert gravel. There is little or no sand on any of the bars or islands. The river meanders in long, irregular curves, but during floods shows little tendency to cut across these meander bends, for the stream does not generally rise high enough above the bottoms or flood plain within the bends to carry a strong current across them. Foster Bend was the only place where cutting across a meander curve was observed. A runway formed here in 1886 badly damaged some of the land. Later floods have not been high enough to reoccupy this runway, so that it has not yet been filled by later deposits.

Just above Poole's ferry a gravel bar has recently been dredged and the channel would seem to be able to maintain itself without the aid of further dredging.

Just below the mouth of the Chattooga there are two gravel bars whose material has evidently been furnished by the Chattooga. This material seems to be carried away to-day by the river as fast as the tributary stream brings it in, so that the bars have reached a stable size and form and are reported not to have changed in the last 40 years.

At Center Landing there are two small islets, each about 150 or 200 yards long and 25 yards wide. These islets have not changed materially within the last 40 years.

Just below the mouth of Terrapin Creek there is a gravel island about 2 acres in area, which rises 3 or 4 feet above ordinary water level and is scored longitudinally by the river floods. Just below it is a shallow gravel shoal. Both of these have been built of material furnished by the creek and, like the bars below the mouth of the Chattooga, have been in equilibrium for at least the last 40 years.

Just below Wood's ferry there is an island, between 5 and 10 acres in area, whose upper end is kept scoured by floods, but whose size and form are reported as unchanged during the last 40 years.

At Gadsden the river is 150 yards wide and its banks are somewhat higher than usual so far down the river; they are 22 to 26 feet in height. The ordinary flood plain is 150 to 200 yards wide and is bordered on the east by an extraordinary one 10 or 12 feet higher, which rises eastward by imperceptible gradations until it becomes fossil and ultimately merges with the general country level. On the west side a bluff rises from the ordinary flood-plain level to an old high-terrace level, whose surface at the west end of the railway bridge is about 71 feet above ordinary water level. Gadsden is situated on this old high terrace. Its surface is composed of a clay stratum, 10 or 12 feet thick, beneath which there is a bed of 8 or 10 feet of well-rounded river gravel, whose average maximum diameter is 2 inches or less, though some pieces reach 6 inches.

This gravel is a rusty, brownish yellow and very much resembles the gravels seen on the lower Tennessee and on the bluffs along the Mississippi above Memphis and may be of the same age. Very few floods are high enough to cover the ordinary flood plain, and the extraordinary one has been covered within recent years only by the flood of 1886, when the stage reached was 36 feet, and even this stage lacked 2 feet of covering the highest parts of this old extraordinary flood plain. The ordinary flood plain is not much injured by the floods that occasionally cover it.

COOSA RIVER BELOW GADSDEN, ALA.

The river was examined some 50 miles below Gadsden, at Riverside, where it is 150 yards wide and its banks are 8 or 10 feet high. The present flood plain on either side of the stream has an aggregate width of some 100 yards, and above it, at a height of 10 or 12 feet, there is an older flood plain, perhaps never reached by floods of to-day, which rises slowly until it merges along its outer edges into the general country level. There were no signs of flood damages and inquiry failed to elicit any information of such damages. Some 40 miles below Riverside the river was examined at Childersburg. At the railway bridge north of the town it is 180 yards wide and has banks 15 feet high, which are covered with trees and quite stable. At this point there seems to be no ordinary flood plain. On the south side is an undulating extraordinary flood plain that slopes gradually upward for a half mile until it merges into the general upland surface. Floods reach its edge or occasionally cover some unusually low runway on its surface. The flood of 1886 is the only one recorded that might be said to have covered any considerable part of this flood plain.

At Chancellor Ferry, 2 miles farther downstream, there is on the north side of the river a fossil flood plain with very gentle slope, separated on its riverward margin by a 10 to 15 foot scarp from an extraordinary flood plain, 50 or 60 yards wide, whose surface is slightly undulating and has been covered only by the very highest floods, such as the one of 1886. It is 15 feet above water level. Immediately above the ferry there is a small island whose outline has not perceptibly changed in the last 40 years. On the south side of the river there is an ordinary flood plain 10 feet above water level, forming a very narrow shelf, and 5 or 6 feet higher an extraordinary one, which is 150 yards wide and rises gradually in this distance some 12 feet, merging into an old fossil flood plain, remarkably level and broad, which extends southward and eastward several miles beyond Childersburg.

Below Childersburg the river was again examined at Montgomery and at Selma, but the conditions at these places, both of which are on the Coastal Plain, where the whole country is

made of soft sands and clays or partly indurated marl, were so extremely different from the conditions on the middle and upper part of the river system that no fair comparison could be made. Changes in the position of the navigable channel by the formation and growth of bars and islands and by the undercutting of the banks made it an entirely different kind of river from that exhibited in its middle and upper courses.

The middle and upper portions of the river are evidently not much clogged by material eroded from its steep headwater slopes; bars and islands are not growing; the position of the steamboat channel and of the river itself is unchanged. All this is undoubtedly due to the fact that there is comparatively little active erosion in the mountains in northern Georgia, where this stream system heads. Most of the region there is still in forest, and the Coosa presents the best observed example of a stream system on which conditions are still satisfactory. These conditions can, however, be maintained only by adopting preventive measures before lumbering and clearing have started serious erosion and begun to establish the same unsatisfactory conditions that are found on the Tennessee and other streams flowing from the more largely cleared portions of these southern mountains. The accumulation of sand bars and the changes in the stream channel in the coastal-plain portion of Alabama are due to local causes or conditions that are commonly characteristic of large streams flowing with low gradient on broad alluvial plains and can not be attributed to abnormal erosion on their headwaters. If they were they would undoubtedly be producing changes in the low-grade portions of the stream both above and below Rome, Ga. An examination of this stretch of the river showed that no great changes are in progress and that present conditions have been maintained for many years.

CHATTAHOOCHEE DRAINAGE BASIN.

GENERAL CONDITIONS.

The headwaters of the Chattahoochee basin, on the eastern slope of the Blue Ridge, were examined and the river itself was followed across the Piedmont Plateau as far as Atlanta.

The headwater tributaries of the Chattahoochee rise on the southeastern slope of the Blue Ridge and flow for several miles southeastward as if to enter the Atlantic, but are then gathered into a master stream that flows to the southwest and enters the Gulf of Mexico.

The tributaries descend from the crest of the Blue Ridge 2,000 or 3,000 feet in a few miles, and reach the inner edge of the Piedmont Plateau at an elevation of about 1,500 feet above sea level, below which their descent, until they join the Chattahoochee, is probably not more than 20 feet to the mile. Along the eastern face of the Blue Ridge headwater erosion is exceedingly active, and the scarp has been intricately carved into narrow gorge-like valleys, separated by sharp-crested, sloping spurs. This minutely dissected Blue Ridge scarp is in some places rough and rocky, but in others is covered with a residual soil layer. Except along the stream channels themselves it is almost everywhere wooded, though the soil is dry and thin and the forest growth is open and of poorer quality than that at similar elevations on the same range 100 miles to the north. On shaded northern slopes, where there is more moisture, there is a greater accumulation of humus and the forest growth is denser and larger. Most of these headwater streams are bordered by no flood plains until they have descended almost to the level of the plateau, where, at some distance from the base of the hills, a narrow flood plain appears, which rapidly grows broader until it may exceptionally attain a width of a quarter of a mile, a half mile, or even a mile. Some miles farther down, however, these streams begin to incise their channels beneath the plateau level and soon flow in narrow gorges whose depth increases until in many places it reaches 100 to 200 feet. Few of these gorges have flood plains and their sides are generally too steep and rugged for cultivation. Such, for example, is the character of the Chestatee near Dahlonega, of the lower part of the Soque, and of the Chattahoochee itself for a number of miles both above and below the mouth of the Soque.

The general upland surface of the Chattahoochee basin is an old plateau, whose elevation near the head of the river is about 1,500 feet above sea level. It is bounded on the north and northwest by the scarp of the Blue Ridge, which overlooks it, and on the southeast by a somewhat similar but lower scarp, well seen from Mount Airy and other points in its vicinity that overlook the Atlantic portions of the Piedmont Plateau. The Chattahoochee Plateau thus forms an intermediate step, as it were, between the Piedmont Plateau and the crest of the Blue Ridge.

This lower scarp, between the upper part of the Chattahoochee basin and the streams flowing southeastward to the Atlantic, decreases in height southwestward until it disappears in the region northeast of Atlanta, where the Chattahoochee Plateau and the Piedmont Plateau merge into one. The surface of this Chattahoochee Plateau is broken by streams that have incised their channels beneath it and by isolated residual peaks and broken ridges that rise above it. In other words, its topographic relations are exactly similar to those that are characteristic of the Asheville Plateau, or to those of the remaining part of the Piedmont Plateau to the southeast.

These three plateaus are undoubtedly of the same age and were formed by long-continued erosion that reduced each to a low plain, usually called a peneplain, that has since been uplifted, their difference in height being due to difference in distance along their drainageways to the sea. They have undergone the same amount of atmospheric weathering, and where the rainfall, slope, and soil are similar, show the same effects of erosion. The rocks of this Chattahoochee Plateau are like those of much of the Asheville Plateau—deeply decomposed schists, gneisses, and granites. Much of the soil is a red clay and on steep slopes erodes rapidly.

The most serious injury noted in this basin is the filling of the Chattahoochee channel with sand, which is destroying the ferries and threatening to fill several dams recently built to utilize the large water power furnished by this stream. This sand deposit has not yet greatly injured the bottom lands, but with further increase in its accumulation, which is inevitable under present conditions of clean culture on steep slopes and their subsequent rapid erosion, the bottom lands will soon be so covered with sand that in a few years their fertility will be destroyed. With the filling of the dams at power plants and the burying of the rich bottom lands beneath barren sand the river will have practically completed the destructive processes which it is only too evident have already been well begun.

DETAILS OF CONDITIONS.

For a few miles above Nacoochee Valley the Chattahoochee has a narrow flood plain, which is commonly bordered by a terrace 30 feet higher, beyond which runs another one 20 feet higher still, though in some places these two merge into one, forming one old flood plain 50 feet above the present flood plain. Higher up the river there is practically no flood plain, and there is very little clearing along its upper 10 miles, either on the stream itself or on the adjacent mountain slope. Much of this region is rough and practically all of it is wooded.

In the Nacoochee Valley there is a flood plain half a mile to a mile wide, through which the stream flows in a broad, shallow channel 2 to 5 feet below flood-plain level. Along its course there are many gravel bars, which alternate with deep, quiet pools. In most places the channel is bordered by a narrow cobble zone, produced in time of floods. The river sometimes destroys the crops in this valley, but has not greatly injured the lands. At its eastern end Nacoochee Valley is joined by the valley of Sautee Creek. This valley is very similar to Nacoochee Valley, and conditions in it are similar to those just described.

A few miles below the junction of these two valleys the Chattahoochee begins cutting its way beneath the plateau level and forms a narrow gorge that contains little or no flood plain almost down to Gainesville. Here and there in this distance, inside of bends or at the mouths of tributary streams, there are small flood-plain areas, but the aggregate amount of such land is small.

In the Chestatee basin about Dahlonega the upland is an old, well-dissected plateau, whose topographic form is very similar to that of the Asheville Plateau in western North Carolina, and its age and origin are doubtless also the same. Around Dahlonega the soil is a poor mica schist, worth but little for agriculture. In many places it carries considerable quantities of gold, and for years more or less hydraulic mining has been done in this region. The great quantities of material washed in this way to the streams have not caused the complaint from farmers that might be expected, since the swift currents of these streams remove all this material during periods of high water. The streams are actively eroding their channels and have high banks and velocity enough, it would seem, to remove more material than is being furnished them even by the hydraulic mining.

For 7 miles east of Dahlonega, on the road to Cleveland, the numerous small streams have narrow flood plains that are farmed, but the uplands are practically uncleared. Where the road crosses the Chestatee there are some bottoms. On the Little Tesnatee and again at Pleasant Retreat there are excellent bottoms. The uplands about Pleasant Retreat and farther east, toward Cleveland, have much better soil than that around Dahlonega and are much more largely cleared. This soil is a deep clay and erodes in many places much as it does about Asheville, N. C. The small streams show the influence of this hillside erosion and are depositing sand and clay on their flood plains and cutting channels across the meander curves that have begun to form.

North of Cleveland the same conditions—largely cleared uplands, erosion, stream aggradation, and flood damage—also prevail, until the divide separating the Chestatee from the Chattahoochee is reached.

In the upper part of Soque River basin much of the upland is poor and comparatively little of it has been cleared. Along most of its small tributaries there are narrow flood plains, and on some streams the lower 50 yards of adjacent hillsides are cleared, although the aggregate of such clearings is less than 10 per cent of the area. In places two-thirds of the cleared land has been worn out and abandoned. In some localities it is gullying, in others it seems to be growing up again in forest.

The Soque is bordered by a flood plain from a point near the mouth of Shoal Creek down to a point some distance below Clarksville, where it begins to cut sharply beneath the plateau level and develops a gorge, just as the Chattahoochee does below Nacoochee Valley.

Less than 15 per cent of the uplands along the Soque above Clarksville is cleared, and on the steep southern slope of the Blue Ridge there is practically an unbroken forest cover, though this cover here, as elsewhere in this region in similar situations, is thin and the timber is inclined to be scrubby.

From a point below Clarksville toward Mount Airy and down the Chattahoochee, more than half of the plateau surface is cleared. Much of it has been farmed for years, and in many places it is eroding badly, especially where the rocks are granitic or gneissose. Where they are micaceous schists the soil is usually full of small rock fragments and is more porous, and erosion is less rapid.

Deep Creek enters the Soque from the northeast about 2 miles above Clarksville. A large part of its basin is comparatively level and 50 to 75 per cent of it has been cleared. Much of its area is a sandy clay that erodes readily, and from this basin great quantities of sand have been carried into the Soque and have almost filled its bed, so that ordinary water level is now but little below flood-plain level. During floods immense quantities of this sand are spread over the bottoms and have greatly injured them. About Clarksville much of the river bottom has been set in Bermuda grass, which seems to prevent erosion better than anything else and at the same time stands being covered by floods better than other grass.

The basins of Flat Creek, White Creek, and Mossy Creek are generally fertile and have been largely cleared. In these basins rainfall gathers quickly and floods are usually high and do much damage. Three weeks before the region was visited in 1905, floods on these streams had swept away a number of bridges and damaged growing crops 25 to 50 per cent, besides severely damaging the lands themselves in many places.

Mud Creek basin has been cleared to much the same extent and is eroding in the same way. The uplands between it and the river are 60 to 70 per cent cleared, and much of this cleared area has been badly gullied and is now abandoned.

At Bolton Ridge the channel of the river is reported to have filled greatly with sand within the last few years, so that floods now occur much more frequently than formerly. There is a well-preserved old terrace at 60 feet and another 20 feet higher. The higher slopes are 80 per cent cleared and 10 per cent of this area is eroded and abandoned.

At Seven Island Ford the injuries and benefits from floods are said to about balance each other; crops are damaged to a considerable extent every five or six years, and at somewhat longer intervals a crop is entirely lost. Intermediate floods enrich the lands.

At and below Clark's bridge the ordinary flood plain is 15 feet above the water level and shows considerable flood scour. About 60 feet above it is another fossil flood plain with a red, loamy, fertile soil that overlies a cobble zone, and 40 feet higher are poorly preserved remnants of another still older flood plain. The edges of this older flood plain are steep enough to erode badly when not terraced. More than a third of the uplands has been cleared, and when old these fields erode unless terracing is practiced. Farmers in this region have lately begun terracing their lands as the only means of preventing erosion under the cultural conditions that prevail where cotton is the principal crop, and where, as a consequence, the land must be kept clean.

From Gainesville down to Atlanta 60 per cent of the uplands on either side of the river are cleared. On some of the poorer soils the clearing is not more than 40 per cent, but in others the proportion rises to 80 or 90 per cent. Much of the soil in this area is a deeply rotted granite, and everywhere the old plateau surface has been carved by erosive agencies into forms that are as a rule sharply rounded. These uplands are practically all kept in cotton, and where they are not terraced erosion is rapid. Practically all of the small tributary streams on both sides of the river carry enormous quantities of sand into the river. The channels of many of these streams had filled so that it was impossible to drain their flood plains, and the lands along them had become practically worthless. The flood plains of others had been covered by sand or cut to pieces during floods and rendered useless. The sand brought down by these streams has accumulated in low-gradient reaches of the river so as to practically fill the channel.

At Stringer's ford the North Georgia Electric Co. has developed power by a dam 36 feet high, which backs up the water 8 miles, to a point beyond Clark's bridge. This dam was completed July 4, 1904, and signs of filling with sand and silt were apparent a year later. This filling must steadily increase and will ultimately destroy the storage value of the dam and force the company to depend on the capacity of the stream alone.

At Shallow Ford there is an ordinary flood plain 6 to 8 feet above the water level, and an extraordinary one 12 feet higher, which in 1905 had recently been cut to pieces in places by unusually high floods. About 40 feet above the extraordinary flood plain is an old, well-preserved terrace, and 40 feet higher is still another terrace, which is, however, poorly preserved. In the bed of the river sand has lodged on bars, behind piers and projecting rocks, and wherever opportunity has offered. The stream is evidently overloaded with such waste.

At Brown's bridge the river is 150 yards wide. The ordinary flood plain is 10 to 12 feet above water level and aggregates on both sides 75 yards in width. Floods had recently destroyed about 10 per cent of the crops, but had not injured the land. There are two terraces, one 15 and the other 60 feet above the flood plain.

At Shadburn's ferry the river channel has been greatly filled with sand, so that the running of the ferry during the summer and fall has become exceedingly difficult. Late in the winter the sand is swept out by floods, but it begins to accumulate again early in the spring. Floods are reported to be more frequent than formerly, and the annual damage to crops averages 15 to 20 per cent. Forty years ago the river was deep at this point and accumulations of sand were unknown.

At Pirkle's ferry it was reported that sand has been filling the channel for the last six or eight years, and that it had prevented ferrying for more than half of the time during the last four years. The conditions here have steadily grown worse, and the owners of the ferry have petitioned the county court to be allowed to discontinue it as a public thoroughfare. Ten or fifteen years ago horses frequently swam the river at this point; now sand has accumulated in quantities so great that a flatboat drawing 6 or 8 inches can not cross during more than half of the year. The river is now muddy most of the time, whereas it was formerly clear.

Baldridge, Twomile, Fourmile, and Sixmile creeks have basins that are very largely cleared and farmed in cotton. They furnish immense quantities of sand to the river.

At Strickland's ferry the channel began filling with sand 8 or 10 years ago, and conditions became so bad 2 years ago that the ferry was discontinued and a bridge was erected instead. The bottoms here are good and are several hundred yards wide; they are injured by some floods and are benefited by others, since floods of one stage erode and those of another stage deposit fertile sediment. The flood plain is bordered by a 60-foot terrace, the steep edge of which is eroding in places. The small creeks on the west side of the river, like those farther up, are filled with sand and have greatly injured or entirely destroyed their bottom lands.

At Terry's ferry the river banks are 8 to 10 feet high and floods frequently destroy crops, but rarely cut the land to pieces. In the last six years the channel has so filled with sand that the ferry has practically been abandoned.

At Hutchin's, Maynard's, Roger's, Abbot's, and Warsaw ferries the same difficulties from the channel filling with sand were found to exist, and at some times of urgent need for ferriage temporary ferryboat channels through the sand had been made with horses and scrapers. These ferries are now being abandoned, and in the place of some of them bridges will be built, though the cost of bridges prohibits their immediate erection by the county at each of the ferries, and much inconvenience to the people on either side of the river is occasioned by this forced abandonment of long-established crossing places. Bottom lands near these ferries are in places a half mile wide. They are not generally hurt by the floods, but crops are frequently seriously damaged or totally lost, and the frequency and severity of this loss has become much greater since the river channel has filled with sand.

An examination of the profile of Chattahoochee River shows that the gradient along this part is in many places less than 1 foot per mile, so that the stream at ordinary stages is not able to remove the amount of sand furnished by its tributaries. The excess, therefore, accumulates in the channel and fills it until continued or repeated high waters in late winter and early spring scour it out.

At Jetts and Johnsons ferries there is no serious inconvenience from the accumulation of sand, since the river gradient has increased to nearly 9 feet per mile and the sand is kept moving.

At Bull Sluice the Atlanta Water Power & Electric Co. had recently completed a dam that gives a head of 50 feet and backs the water up to the highway bridge at Roswell. It will be interesting to watch the gradual accumulation of sand above this dam and the decrease of storage capacity, which is bound to occur unless erosion in the upper Chattahoochee basin is checked. The water wheels installed have a larger capacity than is warranted by the normal flow of the river, so that they are designed to take advantage of the flood discharge as well as the storage capacity of the dam.

At Powers Ferry the stream gradient again decreases and sand accumulates. Floods have injured the lands somewhat by spreading sand over them, but the chief damage is done to the crops. On the east side is a 60 or 70 foot terrace; on the west side a considerable area is covered with sand or cut into holes.

At Paces Bridge an old terrace 70 or 80 feet high, on the west side of the stream, has long been cultivated, but its steep sides are now eroding. The present flood plain is cut by numerous flood runways and is covered here and there with barren white sand.

SAVANNAH RIVER BASIN.

GENERAL CONDITIONS.

The northwestern boundary of the Savannah River basin is formed by the crest of the Blue Ridge. Measured along its windings, the bounding line extends for 100 miles in northeast Georgia and southwestern North Carolina, though in an air line the distance is only 55 miles. From the crest of the Blue Ridge the basin extends southeastward to the Atlantic Ocean. The mountain headwater streams of the basin were examined, and the Savannah itself was followed out across the Piedmont Plateau nearly 100 miles, more than halfway to the outer edge of this plateau.

The principal headwater components of the Savannah system from southwest to northeast are the Tallulah, the Chattooga, and the Little Keowee rivers. These streams, like those in the Chattahoochee basin, descend from the crest of the Blue Ridge scarp, 1,000, 2,000, or 3,000 feet for the first few miles, where they reach the inner edge of the Piedmont Plateau at an elevation of 1,000 to 1,200 feet above sea level. The Tallulah, however, whose middle and upper course is in a higher plateau than the South Carolina Piedmont, is exceptional, for near its mouth it crosses exceedingly resistant quartzose rocks that have prevented it from cutting its channel as deep and reducing its basin as low as those of the other streams of the system. The river falls 525 feet in 2⅝ miles in crossing these resistant rocks. The gorge developed below the falls, though exceeded by many others in depth, is unsurpassed for beauty and wildness in the southern Appalachians. The State of Georgia has created a small park to include the falls and insure their permanent preservation.

In crossing the Piedmont the Savannah and its tributaries flow with relatively gentle slope, and in their course of 150 miles descend, as a rule, less than 1,000 feet. This gradient is by no means uniform, for most of the fall is concentrated at certain places, where rapids occur. Between these rapids the gradient is slight and the current gentle. On Savannah River, for instance, at Calhoun Falls, there is a fall of 10½ feet per mile for 7 miles, but for the next 26 miles the fall is less than 2 feet per mile. Below this point Long Shoal has a fall of about 8 feet per mile for 4½ miles, when the rate again drops to less than 3 feet per mile for the next 22 miles.

On reaches of low gradient flood plains appear and fertile agricultural lands may be found. Where the gradient is high, flood plains disappear, but there is opportunity for the development of water power. What is true of the Savannah River is equally true of other Piedmont rivers to the northeast. On Catawba River, for example, there are three falls within 4 miles, whose aggregate horsepower is said to be greater than any other power developed in the United States except Niagara. A third of this power is already developed and another third is being developed as rapidly as construction can be pushed. Other large powers are found on this river, both above and below this group. Some of them have been developed; others are not yet utilized. Great power is developed on Yadkin River at the Narrows, and plants have been built on other streams in this section. Regularity of stream flow and freedom from silting and from exceedingly high floods become, then, extremely important to towns and manufacturing companies within a radius of 100 miles of these plants, which transmit electric current that distance for generating heat, light, and power.

TALLULAH RIVER.

The extreme upper part of the basin of Tallulah River lies in North Carolina. On the steep southern slopes of the Blue Ridge it is a practically untouched forest, since it is at present far from transportation. South of the Georgia line the stream begins to develop a narrow flood plain, especially near the mouths of its upper tributaries. This land is cleared and sustains no damage from floods, for the velocity of the stream is great and its channel is deep enough to carry most of its flood waters.

From a point a few miles below the Georgia line small flood plains and narrow gorges alternate for some 10 miles down the stream. The flood plains occur mostly near the mouths of tributary streams or on the concave side of bends; the gorges occur where the river cuts across the more resistant rocks.

On Calhoun River there are two small farms. The rest of its valley is in spruce and laurel, and the mountain slopes are in unbroken forest.

On Plum Orchard Creek the bottoms are narrow and the soil is poor. In a few places these bottoms and the lower slopes are cleared, but practically the entire creek basin had been recently sold to a lumber company. Most of the families along the creek had moved out and their little clearings had been turned out to grow up in forest once more.

On Persimmon Creek there are a number of areas of poor bottom land, and in places the lower hillsides have been cleared, worn out, and abandoned. Here and there are remnants of an old 60-foot terrace, whose slope in some places is of red clay and where cleared has generally been gullied. As a rule, however, in the Tallulah basin, old cleared lands wear thin, but do not usually cut into gullies, for the soil is more or less porous and is filled with small stones.

On Popcorn Creek the first settler was not injured by floods for a number of years. Later some 20 families moved into the basin above him, began clearing the narrow bottoms and the lower hillsides, cutting roads, and burning woods, and within a few years floods began destroying his bottom lands.

Throughout the upper part of the Tallulah basin much damage has been done by forest fires, and their results have been so serious that measures have been taken in the last few years to prevent them. Not only did the fires destroy much timber, but the floods that followed were considered to be more severe than they would otherwise have been.

On Dicks Creek, near its mouth, there are some good bottom lands, but elsewhere on the stream there is but little bottom and the lower slopes of the bounding mountain side are cleared in but few places. Nearly all of the families on this creek have sold their holdings to a lumber company and moved out.

Timpson Creek along its lower 3 miles is bordered by bottom lands that average several hundred yards in width. They are the best lands on any tributary of the Tallulah. The slopes on both sides are cleared for several hundred yards and have in many places been worn out and abandoned. The land here does not gully, but wears thin. Floods on this stream do more damage than on any other stream in the basin. At several places remnants of an old 60-foot stream terrace may be seen. This terrace has very largely been cleared, but much of it has been worn out and abandoned to grow up in briers and bushes.

At Burton and for 3 miles below that place there are some excellent bottom lands on the Tallulah. The river flows with a swift current within banks that average 6 to 8 feet in height, and though floods frequently cover the bottom they enrich rather than injure it. Crops are, however, frequently injured or destroyed. Three miles below Burton the flood plain is 300 or 400 yards wide; the stream is rapid, with banks 6 to 10 feet high, and there is a well-preserved terrace 55 feet above flood-plain level, with abundant 8 to 12 inch cobbles on its surface. Its slopes have long been cleared and have eroded until they are practically worthless.

Along Bridge Creek there are some fertile bottoms that are in places a hundred yards wide. Near the stream there is usually a narrow cobble zone, produced during floods. A few of the lower hillsides have been cleared, worn thin, and abandoned. At the mouth of Bridge Creek there is a 10-acre bottom in good condition. Below that point there are numerous remnants of two old terraces at elevations of 40 and at 80 feet, respectively, above the present flood-plain level. There is, however, comparatively little bottom land along this creek. The valley sides are steep and rough, and, along with the higher ridges, are still in original forest. At intervals down to Tallulah Falls patches of bottoms, each a few acres in extent, are found here and there, but most of the area is uncleared. Below Tallulah Falls the river flows in a canyon for 2 miles to its junction with the Chattooga. It is believed that certainly less than 10 per cent and probably less than 5 per cent of the entire area of the Tallulah basin is cleared.

FROM RABUN GAP TO TALLULAH FALLS.

The streams between Rabun Gap and Tallulah Falls have generally narrow flood plains, most of which have been cleared and are in cultivation. In some places the soil on the valley side is fertile, and clearings have been made 100 or 200 yards up the valley slopes. These lands have worn thin, much as have those in the Tallulah basin that have been long cleared, and many fields have been abandoned. Away from the streams the country is entirely forested. Along the streams there are no marked evidences of erosion by floods, and, in fact, floods are usually regarded as beneficial, for they enrich the bottoms with fertile sediment. Less than 10 per cent of this area has been cleared.

CHATTOOGA RIVER.

Chattooga River heads in Cashiers Valley and flows southwestward some 60 miles to its junction with the Tallulah, where it turns southeastward to cross the Piedmont Plateau on its way to the Atlantic. In its upper course, except in Cashiers Valley and Whiteside cove, the river flows in a narrow gorgelike valley whose slopes are wild and uncleared. Five miles above Russells Bridge a narrow flood plain, in places 200 to 300 yards wide, begins and extends some 4 miles below the bridge. The river flows with a swift current between banks 10 to 12 feet high; floods cover the lower part of the flood plain, but in the last 36 years at Russells the river has extended from hill to hill only once—in June, 1876. A similar flood occurred in 1835, but the relative height of these two floods could not be ascertained. The flood of 1876 destroyed all crops, but improved the land; and the same may be said of ordinary floods that cover only the lower part of the flood plain.

Four miles below Russells the valley walls close in and the river flows in a rock-bound gorge, 500 feet deep, to the mouth of the Tallulah. The fall in the 29 miles from Russells Bridge to the mouth of the Tallulah is 810 feet, or nearly 28 feet per mile.

At Russells there are on the South Carolina side of the river a few remnants of a terrace 60 feet above the present flood plain; on the Georgia side terrace remnants appear about 80 feet above the present flood plain, and though remnants on numerous spurs up and down the river differ somewhat in elevation, this terrace would seem from its proximity to the 60-foot terrace on the Carolina side to represent an older and higher flood plain.

The river is actively eroding its bed and is deepening its channel. The sediment carried either at ordinary times or during floods is relatively small in quantity and does not accumulate in the channel, but as the water spreads over the flood plain the checking of its velocity causes deposition and the deposits build up the flood plain. In this way the interval between the stream bed and the flood-plain surface is constantly becoming greater, and a considerable part of the flood plain is now above the reach of all but the highest floods. In the stream many of the rounded bowlders are a foot or more in diameter.

Along War Womans Creek are some narrow flood-plain areas, most of which have been cleared; but only one, 8 miles east of Clayton, is of considerable size. On the lower 100 to 200 yards of the valley slopes are many cleared areas which have washed badly and have then been thrown out to grow up again. Considerable lumbering has been done on this creek, and some of the bottom lands have been damaged by floods.

Between Russells Bridge and Highlands less than 5 per cent of the upland has been cleared and comparatively little timber has been cut because of the distance to transportation lines. This land is passing rapidly into the hands of lumber companies, which up to 1905 had been paying from $1 to $2 per acre, with prices steadily rising.

Along West Fork the narrow flood plains and a small part of the lower slopes have been cleared. The soils wear thin, but are generally stony and do not gully. The higher slopes and ridges are uncleared.

The upper part of Clear Creek is bordered by a flood plain which is 200 or 300 yards wide and is cultivated. The valley slopes, especially on the northwest side, have been cleared

in many places, and near the head of the creek scattered fields extend well to the top of the ridges or to the foot of the precipitous face of Mount Satulah. Some of the fields on the lower slopes are old and somewhat gullied, but the effects of erosion were nowhere prominent along this creek.

On the road from Russell to Walhalla both the east and west slopes of Chattooga Ridge are wooded. Below the point where the road crosses Taylor and Village creeks there is a tract comprising 30 to 40 acres of cleared bottom land, which is of medium fertility and near the stream channel shows some erosion. A few acres of the lower slopes are also cleared. The forest extends to Jerrys Creek, where there is another narrow cleared flood plain. The country is wooded across Stump House Mountain except for two farms aggregating 40 to 60 acres of fairly level but poor land on top of the mountain.

From the ridge east of this mountain the rolling surface of the Piedmont Plateau extends eastward to Walhalla and far beyond and is largely cleared. Many of these Piedmont hills are eroding and furnish great quantities of sand to the streams that drain them. From Walhalla to Westminster the Piedmont uplands are rolling to hilly and 60 to 70 per cent cleared. Where their slopes are of red clay they have gullied considerably.

Coneross Creek cuts across upturned crystalline rocks, and as these vary greatly in resistance to weathering and to stream erosion, its valley is alternately broad and narrow. Where the valley is broad the stream is bordered by a fertile flood plain, 100 yards or more in width; where it is narrow the flood plain is absent and the stream flows in a gorge-like channel. This condition causes ponding on the broader areas during floods and a deposition of fine sediment just above the constrictions in the valley. The velocity of the current increases greatly through the constricted places and causes rapid scour. Below such a constriction the stream again spreads out, loses its velocity, and deposits a broad sheet of sand over the fertile bottoms, and may ruin the upper half of the next flood-plain area below. Such topographical relations and erosion results are seen along many streams on the Piedmont Plateau.

CHAUGA RIVER.

When examined in the midsummer of 1905 Chauga River had recently been in high flood, during which there had been much gouging and scouring on curves and deposition of large quantities of barren white sand in places where the flood plain was constricted. Below the constrictions all crops were ruined, and moderate estimates place the damage to the bottom lands themselves at half their value. All but two highway bridges on the stream were swept away, and the steel bridge on the main line of the Southern Railway was also carried out, tying up traffic for several days. Near the mouth of the Chauga the water reached into buildings that had never before been flooded. The upper part of the Chauga basin is not greatly cleared, but it had recently been quite thoroughly lumbered, and the severity of the flood was generally attributed to this fact.

HIGHLANDS TO TOXAWAY.

Between Highlands and Toxaway the only considerable area of cleared land is in Cashiers Valley, on the head of Chattooga River. Slopes there are low, and the soil, which has been derived from the disintegration of a granite, is poor, gravelly, and generally porous. Though much of this valley is in old fields, erosion is not marked. Below it, in Whiteside cove, lands are steeper and about 15 per cent of the cleared area shows evidence of erosion. Some of it has been abandoned. In the upper part of the Horse Pasture basin a few clearings appear on the stream bottoms and lower slopes, but almost the entire basin is wooded. Near Lake Toxaway there are a few farms.

The basins of White Water, Horse Pasture, and Toxaway rivers contain some of the finest areas of hard wood, white pine, and hemlock to be found anywhere in the southern Appalachians.. They are largely owned by lumber companies.

TOXAWAY TO WALHALLA.

Northeast of Lake Toxaway there are some small cleared tracts along the top of the Blue Ridge. Some of these clearings have a close-grained red-clay soil and are gullying. Several of the tributaries of Toxaway Creek are bordered by narrow flood plains that are largely cleared, and a little of the immediately adjacent valley slopes is also farmed. Most of the basin, however, is in original forest.

Along Laurel Creek there is a little cleared land, but Laurel Branch Mountain is entirely forested except for one old field near its top. Practically the entire country visible from its sides and crest is forested.

Big and Little Estatoe rivers are bordered by flood plains that are 100 to 300 yards wide and are generally in good condition as regards erosion. The lower 100 to 200 yards of the valley slopes are cleared. Where the slopes are gentle the cleared land is in good condition, but where they are steep they begin to erode after a few years' cultivation. Above these uplands, of which about 40 per cent is cleared and in cotton, rise many small residual mountain peaks or ridges that are practically all forested.

On Crow Creek the bottoms are a few hundred yards wide and have been damaged by floods. The bordering slopes and uplands are for the most part cleared. Where the soils have resulted from the weathering of granites they are eroding; where they have been derived from hornblende schists erosion is much less prominent.

Remnants of an old 60-foot terrace appear along practically all the streams in this area, though the elevation in some places drops down to about 40 feet and in others rises to 70 feet. It seems probable that this variation is due to local variations of rock resistance and of valley width and that the terraces are therefore of the same age. The scarps or slopes of these terraces in many places show gullying.

On Keowee River flood-plain areas a few hundred yards wide on soft rocks alternate with constricted reaches cut through hard rocks, on which a flood plain is practically absent. The velocity of the stream is relatively great and its banks are as a rule high. Floods cover the bottom lands and destroy crops, but are reported to benefit the lands more frequently than to injure them. West of the river the uplands for several miles are poor and forested. Active lumbering was in progress when the region was examined.

The valley of Little River is to a large extent cleared. Many of the slopes were eroding, as are also slopes along other creeks between Little River and Walhalla. On several of these creeks floods had recently destroyed much of the crops and in places had ruined the land either by gouging or by covering it with sand.

TUGALOO AND SAVANNAH RIVERS DOWN TO SEABOARD AIR LINE CROSSING.

From the junction of the Tallulah and the Chattooga the Tugaloo flows 48 miles to its junction with the Seneca, where its name changes to the Savannah.

The average fall of the Tugaloo in this 48 miles is somewhat more than 5 feet per mile, but it is concentrated at a few places. Between these places the rocks are less resistant and the average slope is much lower. In the 35 miles from Prather Creek to Averys Ferry, for example, the average fall is less than 3 feet per mile.

Below the mouth of the Seneca the Savannah is characterized by a similar succession of rapids and low-gradient reaches as it crosses the alternating belts of hard and soft rock. The average fall is 2 or 3 feet per mile through the entire distance of 149 miles to Augusta, Ga.

Along the low-gradient stretches of the Tugaloo and the Savannah the velocity is so slight as to permit sand to accumulate in the channel wherever the tributary streams furnish it in large quantities. So far this deposit of sand has not reached the serious proportions attained on the Chattahoochee, but it no doubt marks the beginning of a similar condition, which may be expected to become worse each year. As clearings are extended and erosion becomes more universal, the quantity of sand furnished the stream will steadily increase, the excess will

be deposited first in its channel and then over the flood plain, until the value of the bottom lands has been destroyed and the power dams along its course have been filled, when the ruin capable of being wrought by the stream will have been completed.

The Tugaloo has very little flood plain for 6 or 7 miles below the mouth of the Tallulah. Thence to the mouth of the Chauga, about 8 miles, the flood plain is from a fourth to a half mile wide and is fairly fertile. The river in most places flows between high banks, and floods, though frequently covering the land, rarely injure but rather enrich and benefit it. These floods, however, often ruin crops and have of recent years been more frequent than formerly. Farmers along the river claim that they now lose an average of one crop out of every three or four. On July 1, 1905, three weeks before this region was examined, a severe flood had occurred, and from one-third to three-fourths of the corn on the river bottom had been destroyed. In some places nothing was left growing; everything was covered by a deposit of mud 6 to 15 inches thick.

On Brasstown Creek the bottoms are good and average 300 yards in width. The slopes have not been largely cleared, but when examined the entire basin had lately been lumbered, and the recent flood had swept away cribs and barns that had never before been reached.

Panther Creek also did much damage at this same time, but the destruction was due to the cleared condition of much of the basin and not to lumbering. In one place the creek had recently shifted its channel during a flood and left a mill high and dry.

Near Prathers Bridge the lands along the small creeks were greatly damaged by the recent flood. The creeks were universally reported to have been higher than ever before known. Many bridges were swept away in the region, and moderate estimates placed the damage to the bottom lands at one-third to one-half their value. The destruction of crops was in most places complete. On the river bottom at Prather all of the crop was destroyed; below Prather the creeks entering from the east side down to Fort Madison had destroyed half to three-fourths of the crops growing along them. In some places the lands were badly injured, but in others they were covered with rich alluvial material and greatly benefited. Just above Fort Madison the river had spread sand over a part of its flood plain adjoining the channel.

At the mouth of Rock Creek the river had scoured and cut to pieces the bank on the convex side of the curve and the crops for some miles above and below were reported as a half to a total loss.

At Perkins's ferry there is an ordinary flood plain 6 feet above water level and 20 feet wide, and 8 feet higher an extraordinary flood plain, bordered on its river side by a low sand ridge, which has in recent years been repeatedly submerged. The growing crop had been lately damaged from one-half to three-fourths its former value. In places lands were reported injured, in others benefited.

On Estanolle Creek the greater part of the valley has been cleared and planted in cotton. Many of the slopes are steep and are washing badly where terracing has not been rigorously and systematically practiced. The stream carries much mud and great quantities of sand during floods. Its channel has been filled with sand and its floods do proportionately more damage to the lands along it than those of the river do. Much of its flood plain is either covered by sand or cut into holes. This sand works into the river during floods and is helping to overload it and cause the ultimate filling of its channel, just as the creek channel has already been filled.

At Shelor's ferry the bottom land is one-fourth to one-half mile wide and had recently been enriched by a 12 to 15 inch layer of rich soil, but crops were a total loss. Similar reports of ruined crops were received at the mouth of Gun Log Creek and at Knox Bridge. About 50 to 60 per cent of the upland in that vicinity is cleared; much of it is hilly and erodes readily. Some 20 per cent of the cleared land is terraced; of the unterraced land, one-fourth has been badly eroded. The terracing, when properly done, effectually prevents erosion. At the mouth of Seneca River the Tugaloo is 105 yards wide and its banks 5 to 6 feet high. Just at the ferry there is no flood plain, but both above and below it there is one, from a fourth to a third of a

mile wide. Crops on these bottoms had generally been destroyed and the land itself had been somewhat damaged. For the last few years sand had been noted in greater quantities and was beginning to cause trouble in ferrying. It has accumulated during medium and low-water stages, but during high floods, which occur especially in late winter or early spring, it has so far been swept out.

At Brown's ferry the river had recently injured its bottoms 10 per cent and its crops 50 per cent.

At Dooley's ferry so many crops have been lost by floods that the bottoms have been set in Bermuda grass, and some of this had recently been buried under several feet of sand. This grass is undoubtedly the best growth to protect such bottom lands, while at the same time it furnishes an excellent pasturage and is injured by floods less than any other grazing crop.

At Park's ferry a third to a half of the crop had been destroyed, and half of the bottom land had been cut by runways or covered with sand.

For 8 miles below McGee's ferry the valley sides close in on the river, and there are no bottom lands worth mentioning.

At Harper's ferry, where the upland on the west is 160 feet above the flood plain, there is first, at 8 feet above water level, an ordinary flood plain 20 to 30 feet broad; then a sharp rise of 10 feet to the top of a long sand belt which parallels the river and is 100 to 200 feet wide; and back of the sand belt there is a descent of 6 to 8 feet to a fertile flood plain which lies next the valley wall and is covered annually by floods. On the east side of the river the bottom land is 6 feet above water level, and a low sand ridge near the bank rises 6 feet higher. Remnants of an old terrace at 25 to 40 feet are seen here and there. The channel is reported to be filling with sand, and the average depth of the river is said to be notably less than it was 20 years ago.

A power plant on Seneca River is illustrated in Plate XII, *B* (p. 36).

SALUDA RIVER BASIN.

The northwestern border of the basin of Saluda River extends 17 miles along the Blue Ridge and about an equal distance along the Saluda Mountains, the northeastward continuation of the Blue Ridge. The upper part of the basin is a fan-like expansion; the middle and lower parts are extremely narrow and lie between the Savannah basin on the southwest and Broad River basin on the northeast.

The steep southeastern slope or scarp of the Blue Ridge in this basin is relatively simple and abrupt, the drop being in places, as at Cæsars Head or Standing Stone Mountain, practically precipitous. A characteristic view of this scarp and of the Piedmont Plateau below it, looking southwest from Cæsars Head, is shown in Plate XVIII (p. 108). The difference in elevation between the top of the ridge and the plateau below is 2,300 feet. This steeply sloping southeastern scarp is practically an unbroken forest of hardwood. Along its southwestern part lumbering companies had been actively buying within very recent years, at prices ranging from $1 to $3 per acre, and in 1905 some land was still changing hands at these prices.

The headwaters of the stream flow in narrow, rocky gorges, which are being rapidly eroded. Like other streams rising on the southeast face of the Blue Ridge, they descend a distance of 1,000 to 1,200 feet or more in a few miles, reaching the Piedmont Plateau at an elevation of 1,000 to 1,200 feet above sea level. As they reach the Piedmont level their gradient decreases and narrow flood plains begin. These flood plains and more or less of the adjacent lower slopes of the Piedmont uplands are cleared and farmed.

On the head of North Saluda River the mountain sides are practically uncleared. The streams descend with a steep grade and have developed narrow, torrent plains, most of which have been cleared and within recent years have been badly injured in places by abnormally high floods. Their aggregate area, however, is relatively small. Somewhat lower the steep slopes have been more extensively cleared and floods had injured the growing crops from one-third to one-half. Below Humphreys's store lands away from the stream are poor and

uncleared; along the stream the narrow flood plains showed much injury to land and crops. In many places the channel is almost filled with sand. From Terrys Creek to Lima along the North Saluda cleared flood plain areas alternate with narrower uncleared stretches. The river is swift and shallow and is moving great quantities of sand derived from the deep decomposition of the gneisses and granites in its upper basin.

At Cleveland Mills one-third to one-half the crops on the bottoms had been destroyed by floods, and it was reported that crops on the Middle Saluda had been damaged three-fourths of their value. The bottom here is 150 to 200 yards wide and is being cut to pieces by floods. The hill slopes are not generally cleared, but there has been considerable lumbering.

On the South Saluda some narrow flood-plain areas extend well up to its head near Table Rock and are cleared and cultivated. Along the lower course of the stream the bordering slopes are steep and uncleared, but above Venus they become more gentle and clearings extend some distance up either valley wall. A portion of this cleared area may be seen in the view from Cæsars Head in Plate XVIII. From Venus to Cæsars Head there are no clearings of any kind.

BROAD RIVER BASIN.

GENERAL FEATURES.

The basin of Broad River lies northeast of that of the Saluda, and its northwestern border extends 35 miles in an air line along the crest of the Blue Ridge, or 53 miles by its windings. The southwestern side of the basin is drained chiefly by two tributaries, the Tiger and the Pacolet. The headwaters of the Tiger do not reach the Blue Ridge but flow from an outlying mountain mass in the northern part of Greenville County, S. C. The headwaters of the South Pacolet rise in this same detached mountain mass, and those of the North Pacolet flow from the Saluda and Tyron mountains and likewise fail to reach the Blue Ridge. The next tributary of Broad River, Green River, heads in the Blue Ridge and flows northeastward parallel to it for an air line distance of 16 miles before turning to the southeast and cutting through the Saluda Mountains, which are the structural continuation of the Blue Ridge in northwestern South Carolina. After passing through these mountains the Green again turns and flows northeastward, parallel to them, for some 10 miles before finally bending to the southeast to cross the Piedmont Plateau. Some of its tributaries likewise parallel the Blue Ridge, but they flow to the southwest and cut the mountain mass into detached ridges parallel to its general trend.

As a result of this unusual stream alignment the mountain chain that is the structural continuation of the Blue Ridge receives another name, and the so-called Blue Ridge (the water parting between the Gulf and the Atlantic drainage) becomes an inconspicuous divide that lies farther west and no longer overlooks as a scarp the Piedmont Plateau of upper South Carolina, but is separated from it by several more or less parallel ranges. This series of somewhat detached ranges or spurs from the Blue Ridge is grouped about Saluda, N. C. It has been produced by stream activities that, while interesting in themselves, are not pertinent to the purposes of this report.

The steep mountain slopes between the heads of the Tiger, the Pacolet, and the Green River basins are for the most part uncleared, but in places, especially on the upper slopes and rounded crests of the ridges, there are extensive clearings, most of which are kept in grass. Where the soil is porous erosion is not active unless the surface is very steep, but lands with compact clay soil begin to erode after a few years' cultivation. Between 5 and 10 per cent of the mountain areas at the head of these basins has been cleared.

The many small streams between the mountain ridges and spurs flow with rapid currents in high-walled channels, and are bordered by narrow flood plains that reach within a few miles of their heads. Many of these flood plains are torrential in character, having an irregular surface and steep downstream slope and being composed of much coarse, stony material, heterogeneously mixed with sand and clay, but some of them are fertile. During floods these

mountain streams occasionally tear up their small flood plains, but as a rule the flood damage is not serious. Their steep slopes are forested, so that the streams are not overloaded with sand and are consequently able to carry away their storm waters rapidly.

The portion of the Blue Ridge to the northeast, however, within the basin of Broad River itself, has been more extensively cleared, and many of the small tributaries are overloaded with sand and gravel and have practically destroyed the little flood-plain areas along them. Such cleared areas may be seen in the region near Sugar Loaf Mountain, especially on its southeast slope.

GREEN RIVER BASIN.

The extreme upper end of Green River basin is forested, but a narrow flood plain begins a few miles below the head of the river and is practically continuous down nearly to the crossing of the Southern Railway just above Saluda, N. C. This flood plain varies in width, but averages about a third of a mile. In some places it is fairly level and fertile, but in others it is rather a beveled plain than a true flood plain and is semitorrential in character because of the locally steep gradient of the river. Only where the stream gradient is greatly decreased does the flood plain show signs of erosion. Just above the Southern Railway Crossing, for example, some areas have been scoured and others have been covered with sand. Some of the lowest of the bordering valley slopes have been cleared, but much the larger part of the basin is forested. The occasional clearings on the upper slopes and crests of the Saluda Mountains seemed to be in good condition, partly because many were new and others were kept in grass.

Below the Southern Railway bridge the river flows for some 8 miles through the Saluda Mountains in a narrow, rocky gorge. Below the gorge the stream flows with swift current in a broad channel and the valley widens into Green River cove. This cove is about 4 miles long and 100 to 300 yards wide and is inclosed on all sides by mountains. In some places it is level, in others it is gently beveled. Here and there a narrow cobble zone next the stream channel has been swept bare by floods which have not, however, greatly injured the lands. Flood heights are low because of the great velocity of the stream, and much of the land in the cove is above their reach. In a few places the lower valley slopes, especially to the southeast, are cleared for a short distance above the flood plain, but much the larger part is in forest or is rocky and precipitous. Remnants of an old terrace 60 or 80 feet above the present flood plain may be seen here and there.

Below the cove the mountain sides close in and the river flows for a number of miles in a narrow, wooded valley.

The uplands on the southeast are included in the basins of Ostins and Silver creeks and are of the usual Piedmont type, the general surface being rolling to hilly and rising 100 to 150 feet above the bottom lands. These bottoms themselves are narrow, rise gently upward on both sides of the stream, and meet the valley walls in a curve slightly concave upward, giving the valleys a broadly U-shaped cross section, and showing that the stream is slowly eroding its bed while the hillsides gradually weather backward in gentle curves. The streams are just about able to remove the waste furnished by their valley slopes and slightly deepen their beds. Any material increase in their load of waste will stop their downcutting and start deposition and aggradation.

At the bridge over Green River north of Mill Springs the channel is 60 yards wide and the banks some 20 feet high. The bottom lands vary in width up to 150 yards and are rather too sandy to be first-class agricultural land. Floods rarely reach them and flood damages are slight.

On the northern slope of Tryon Mountain only a small area is cleared. In Bright's Creek basin there are some steep clearings, and at the head of Walnut Creek, southeast of Sugar Loaf Mountain, steep clearings average 20 or 30 per cent of the area, and the older ones are gullying.

BETWEEN GREEN AND BROAD RIVERS.

Between Green River and the mouth of Buffalo Creek, on Broad River, the soil of the Piedmont Plateau is poor. The timber is thin and of medium quality. About 30 per cent of the area is cleared. The chief crops are corn, cotton, and small grain. Many of the old fields have worn thin where the land is stony or gullied where it is clayey, and have been abandoned to grow up again in briars and bushes. The small streams carry much sand and at many places have filled their channels and ruined the bottoms along their courses.

Cain Creek is bordered by a narrow but excellent flood plain, with here and there a rod or two of gouged surface or undercut banks. The lower 200 yards of the adjacent slopes are generally cleared. Part of this cleared area is badly washed, and the cultivation of one-half to two-thirds of the area originally cleared has since been abandoned.

Here and there on the mountains southeast of the Pinnacle small tracts have been cleared on benches at various levels. Halfway up the scarp there is a bare, rounded, granite cliff, and the soil on much of the rest of the slope is very thin and would quickly strip off to the bare rock if cleared.

Clearings on Buffalo Creek aggregate not more than 5 per cent of the area and are confined to the bottoms and the lowest slopes. Most of the slope fields have been washed to pieces and abandoned.

ABOVE MOUTH OF BUFFALO CREEK.

Along Broad River itself some good bottoms extend for a few miles above the mouth of Buffalo Creek. Thence practically up to its head the river flows in Hickory Nut Gap gorge, a deep and exceedingly picturesque gorge which is, however, much deeper and bolder below Bat Cave than above it. The walls of this gorge are either steep and wooded or are bare granite precipices, a thousand feet or more in height, but are separated sufficiently to permit at their bases occasional narrow steep-slope clearings along the river itself and to give room for a few houses and summer-resort hotels.

The basin of Reedy Patch Creek comprises much cleared land. The creek is overloaded with sand and is injuring its flood plain.

The basins of Little and Big Hungry rivers are practically unbroken wilderness except for a few clearings about Mills's gap and some narrow but fertile flood plain areas near the junction of the two streams. Lumbering operations were in progress when these basins were visited.

THE SPARTANBURG FLOODS.

In June, 1903, in the vicinity of Spartanburg, S. C., a flood, confined chiefly to the Pacolet, Tiger, and other small tributaries of Broad River, swept away 14 cotton mills and many bridges and houses and destroyed more than 50 lives. The property loss involved was not less than $3,500,000.[a]

All the streams of the devastated area rise on the steep slopes of Glassy, Saluda, or Tryon mountains, and the channels of all except Green River are more or less completely filled with sand and gravel, and similar conditions characterize all of their smaller tributaries that rise on the Piedmont Plateau. The unusually heavy rainfall of June, 1903, found the many stream ways in this region in no condition to remove the waters as rapidly as they once could have done, and the pent-back flood rose to abnormal heights and finally swept away everything in its path.

In this connection the changes that have taken place in the Spartanburg area since 1871 are significant.

Prior to 1871 the uplands north of the Southern Railway were practically uncleared, but at that time the introduction of commercial guano made it possible to grow cotton successfully on these lands and by 1880 or 1885 they had been largely cleared and year after year

[a] For details of this destruction see Water-Supply Paper U. S. Geol. Survey No. 96, pp. 13–19.

were farmed in this crop. For the first few years after being cleared the land was full of humus and readily absorbed a large part of the rainfall, but later, when this humus had been exhausted, the lands began to erode, the stream channels to fill with sand, and the bottom lands—formerly the most valuable in the region—became at first difficult and then impossible to drain, owing to the rise in the ground-water level incident to the filling of the stream channels with sand. Floods became much worse and buried under sand or gouged to pieces other considerable areas, so that the bottom lands are now practically worthless.

Before the period of destructive floods the bottoms had furnished the corn supply for the county. The failure of the corn crops necessitated the shipment of large quantities of corn from the upper Mississippi Valley, and this necessity continued for a number of years, until the farmers learned to grow corn on their uplands. Since then they have once more grown the larger part of their corn supply, but in order to do so have trenched on their cotton areas.

At first no attempt was made to check the erosion of the steep slopes of the cleared uplands, but about 1884 or 1885 terracing was begun. The early results were not satisfactory, chiefly because many of the terraces were so poorly constructed that they broke after concentrating the water and caused worse destruction on the lower slopes than if they had not existed. To-day all the best farms are effectively terraced, but many of the smaller farms have not been terraced and upland erosion and stream filling are still active agents of destruction.

In this region rains run off rapidly, the streams rise to unprecedented heights, and during the succeeding dry weather their flow becomes abnormally low. The result of these abnormal conditions is most conspicuously shown by the flood loss of $3,500,000 at one time; but that the low-water damage, if less apparent, is none the less real, is evident from conditions at the cotton mills erected on these streams. These mills report that within recent years the horsepower available during the dry season has decreased one-fourth to one-third. The mills from which these data have been collected are numerous and widely scattered, and the decrease in power can not be explained as either local or imaginary. It is obviously the result of a change in stream regimen.

Another evidence that less of the rainfall soaks into the earth and becomes available to sustain stream flow during dry weather is afforded by the fact that many natural ponds in the Piedmont region, well remembered by men still in the prime of life, have gone dry, not from being drained or filled, but from the drying out of the soil and the failure of the springs that supplied and maintained them—a failure caused by the cutting away of the surrounding timber.

If such results have followed the cutting away of timber on the comparatively gentle slopes of the Piedmont Plateau, it can not be doubted that more rapid and complete disaster would follow the equally extensive clearing of the steep mountain slopes, since their soil, produced by the decomposition of similar ancient gneisses and granites, would yield to erosion with greater ease because of their steeper slopes and greater rainfall.

CATAWBA RIVER BASIN.

GENERAL FEATURES.

The headwaters of the Catawba extend 55 miles along the Blue Ridge, from which the streams flow southeastward, descending rapidly within a few miles from the ridge crest to the Piedmont Plateau, whose surface there has an average elevation of 1,200 feet above sea level. The scarp of the ridge is relatively simple and straight, but is buttressed by many sloping spurs that extend southeastward 6 to 10 miles before they merge into the general Piedmont surface. The narrow valleys carved between these spurs have steep gradients and sharp V-shaped cross-sections. Some of the higher mountain masses on or adjacent to the Blue Ridge have a rich soil and in places have been largely cleared. Northward along the ridge a steadily increasing proportion of these high cleared areas is in grass. The middle and lower slopes are as a rule steeper, rougher, and much less cleared, but within a few hundred yards of stream level cleared areas again appear.

A few miles below the sources of the small streams torrential flood plains begin, which broaden as the streams descend and on the Piedmont level are commonly several hundred yards or, exceptionally, a half mile or more in width.

On the Piedmont the interstream areas are largely cleared. The soils of the Catawba basin are derived chiefly from deeply decomposed micaceous gneisses and granites. In many places these soils erode into deep, vertical-sided gullies, that develop almost canyon-like proportions. They rapidly undercut and cave and soon extend up steep slopes to the hill crests. These are most typically developed along the Southern Railway east and west of Marion (Pl. III, *B*, p. 18) and some miles south of Marion along the railway to Rutherfordton.

At the head of the Catawba and about Round Knob the steep slopes are more heavily forested and much lumbering has been done. Near Round Knob a few small areas have been cleared, but their aggregate acreage is small.

A flood plain begins on the Catawba a few miles above Old Fort and extends almost continuously to Morganton, although it varies greatly in width and in places the walls close in and almost shut it off. East of Old Fort this flood plain is half a mile wide and its soil is excellent; near Greenlee it is one-third to one-half mile wide, and in places remnants of an old terrace appear 50 to 60 feet above the present flood plain. A characteristic view of the Catawba flood plain is given in Plate IX, *B*, page 24.

East of Nebo the uplands begin to be extensively cleared. The cleared slopes in a few years are cut into gullies, and much land has been ruined by this process.

East of Bridgewater the bottom lands show some erosion where the river curves, but where its course is straight there has been no serious damage.

Near Morganton the river banks are 15 to 18 feet high and the stream is usually swift, so that ordinary floods do little damage. In 1901, however, floods destroyed one-third to one-half of the crops on the bottom lands and practically ruined some farms, though the damage to lands was not proportionately as great as to crops. It is claimed that high floods are more frequent in recent years than formerly. In many places a narrow first bottom or ordinary flood plain about 15 feet above stream level is surmounted at an interval varying from 5 to 15 feet by a second bottom, which is, as a rule, much broader and quite undulating, and which is reached by the highest floods. Floods rarely damage this higher flood plain, but at times ruin the crops on the lower part of it, as well as on the entire first bottom. In some places remnants of an older stream terrace or fossil flood plain appear 30 feet above this second or extraordinary flood plain.

From the Catawba Valley near Morganton northeastward to Table Rock post office the upland is rolling to hilly and 10 to 15 per cent of it is cleared. The lands are somewhat stony and the soils wear thin rather than gully. Along Table Rock Creek there is a very narrow but excellent flood plain, a good portion of which is in grass. The slopes are practically all forested and no erosion damages are apparent.

Steels Creek is bordered by a narrow flood plain for a short distance above Joy, but farther up its basin is all wooded.

The road to Pineola along Ripshin Ridge is in an unbroken forest, scarcely an acre of cleared land being visible anywhere within miles on either side.

At the head of Upper Creek there are several cleared areas that aggregate from 100 to 200 acres. Some of these fields are steep and stony and have worn thin. At intervals along the crest of the ridge between Ball Ground and Pineola there are small farms, many of which are in grass. Their general condition as regards erosion is good. The cleared area, however, will aggregate not more than 1 or 2 per cent of the total area within this distance.

LINVILLE RIVER.

Pineola is situated on the broad, flat, and in places swampy flood plain of Linville River. This flood plain is not cleared or farmed to any extent. At Pineola a lumber company had for six years been cutting thirteen to fifteen millions of feet of lumber per year, and in 1905 had a supply sufficient to last several years more. Between Pineola and Linville there is but one

clearing, and that comprises only a score or more acres. At Linville 75 to 100 acres along the river have been cleared. A few clearings in the basin above Linville are in pasture, but 98 per cent of the area is in timber, much of which has not even been culled by the lumberman.

From Linville the Yonahlossee Pike extends 22 miles eastward around the southern slope of Grandfather Mountain and along the crest of the Blue Ridge to Blowing Rock. On Grandfather Mountain there is one cleared area of 30 or 40 acres.

Around the southern slope of Grandfather Mountain one may look from the pike to the southeast for miles across a series of thinly wooded spurs and narrow intervening valleys that are practically without a clearing as far as eye can see. This large uncleared area is on the headwaters of Wilson Creek and Johns River.

East of Grandfather Mountain the crest of the Blue Ridge is cleared in places and much of it is in grass. The soil is generally porous and erosion is not prominent, though in a few places fields have been ruined by gullying. The soils are as a rule derived from deeply rotted schists, which give place near Blowing Rock to gneisses.

BLOWING ROCK DOWN JOHNS RIVER TO MORGANTON.

From Blowing Rock the road down Johns River valley descends the mountain at a steep grade, and for several miles there are no clearings. Most of the small mountain-side clearings that then appear have been so recently made that the deadened timber is still standing and erosion has not yet begun. Still farther down the valley the stream has built a narrow torrent flood plain which continues with some interruptions to a point about 2 miles above Globe, where the grade flattens and the flood plain broadens, extending a mile below Globe, with a width ranging from 200 to 600 yards. A mile above Globe, where the swift shallow stream is 40 to 50 yards wide and flows within banks 3 to 5 feet high, there is near the stream channel a washed zone that is 25 yards wide and extends some distance. The flood plain at that point is only 75 to 100 yards wide and is fairly fertile. A mile below Globe the valley walls close in and from this point down to Collettsville the bottom lands are absent or narrow. Most of the steep slopes and all of the ridges are uncleared, though they have been quite thoroughly lumbered since the building of the railway to the John River valley.

A few miles down Johns River from Collettsville the uplands are of the usual Piedmont rolling or hilly type, have been largely cleared, and in many paces are eroding. The river valley is relatively narrow and the flood plains are more or less disconnected and vary greatly in width, which ranges from almost nothing to 200 or 300 yards. In many places they have been injured by floods, and within recent years many crops have been destroyed.

At the bridge on the Catawba just north of Morganton the flood plain of the river is narrow and shows many visible signs of extensive scouring and gouging during floods. The river valley contracts at this point and for miles down the Catawba the flood plain is narrow or absent, except near the mouths of tributary streams or on concave sides of bends. In this narrow valley the river flows with great velocity during floods and has caused much damage to lands and crops, as well as to bridges and dams.

Where the Southern Railway crosses the river east of Hickory much of the flood plain, which is there 200 to 300 yards wide, has been ruined by the runways cut across it or by sand that has spread over it a number of feet deep, and many once-fertile areas have been abandoned. The stream is broad and shallow and its channel is well filled with sand.

YADKIN RIVER BASIN.

GENERAL FEATURES.

The Yadkin basin lies northeast of the Catawba, and its northwestern margin, for an air-line distance of 70 miles, is formed by the crest of the Blue Ridge. From Blowing Rock northeastward for 45 miles in an air line to Roaring Gap the Blue Ridge scarp does not descend abruptly to the Piedmont Plateau level, but is buttressed by many more or less parallel

spurs whose sloping crests extend southeastward 8 to 10 miles before ending on the plateau. These spurs represent a part of the mountain mass that during long ages has been deeply dissected by the headwater tributaries of the Yadkin, which are steadily gnawing into the mountain divide at their heads and slowly but surely pushing it westward, so that the Atlantic streams are gaining in length and drainage area at the expense of the Mississippi Valley streams.

Most of the buttressing spurs east of the Blue Ridge have steep lateral slopes, which in places are rocky, and as a rule their soil is poor. Here and there on gentler slopes are more fertile areas, many of which have been cleared. Some of the streams between these spurs are eroding their channels so rapidly that they have narrow, sharp-bottomed valleys without flood plains, and the whole basins of such streams are generally forested. Where, however, down-cutting is less rapid or has already reached its limit, or where the valley walls are less resistant and have weathered back more rapidly, the streams have built small flood plains. These flood plains and the better parts of the lower 100 to 300 yards of the adjacent valley slopes are cleared, and a considerable portion of them is usually kept in grass. The flood-plain clearings as a rule show no injury from floods, but the slopes, unless kept in sod, gradually wear thin or wash away.

Just east of Blowing Rock, on the very headwaters of the Yadkin, narrow flood-plain areas occur and some of the adjacent slopes are farmed. As a rule the soil is porous or stony, and the effects of erosion are not serious. Below the headwater region, however, there is but little cleared land along the stream for a number of miles.

At the mouth of Mill Fork is a flood plain several hundred yards wide which extends up Mill Fork and down the Yadkin, but flood plains are not conspicuously developed for some miles below the mouth of Mill Fork until the Yadkin turns to the northeast and begins its long course parallel to the Blue Ridge. For several miles below this point the flood plain ranges in width from three-fourths of a mile to a mile. It then narrows for a mile, and then broadens to three-fourths of a mile or more for the next 2 miles, and this alternate broadening and narrowing is characteristic of the river for a long distance. Where the flood plain narrows it is commonly bordered by a finely developed terrace, 40 or 50 feet higher, with an extremely well-preserved level or gently rounded surface and definite, well-marked scarps. The interval between this fossil flood plain and the living plain becomes gradually greater downstream.

On Elk Creek bottom lands are not found along the lower 5 miles; above that the valley widens somewhat and contains several good farms, but their bottom lands have been greatly injured by floods in recent years. The slopes are broken and rough, but are cleared in many places and are eroding.

Stony Fork and West and East forks are much like Elk Creek. Most of the land in these and other basins on the east slope of the Blue Ridge has passed into the hands of lumber companies, the average prices recently paid being reported as $3.50 or $4 an acre. When examined, this region lacked road facilities for marketing the lumber.

From the mouth of Elk River to Wilkesboro the hills in many places close in on the river and practically cut off the bottoms, but between these contracted portions are broader stretches, with a fertile flood plain a fourth to a half mile wide.

At some points, especially on the concave side of bends, this flood plain has been swept bare by floods, but elsewhere it is in good condition as regards erosion.

Along the valley walls are many remnants of an old cobble-strewn terrace whose average elevation is here about 60 feet above the present flood plain. Above it the valley walls rise gently and irregularly.

Many of the slopes have long been cleared, and on these clearings erosion is more or less prominent almost everywhere.

The Brushy Mountain Range, on the south side of the valley, is forested to its tops, though some scattered clearings have been made on its upper slopes. These clearings, many of which are kept in grass, seem to be free from erosion damages. Along the small streams between the spurs of the mountains there are narrow flood-plain areas, and these, as well as the little amphitheater-like coves at the heads of the streams, are generally cleared. Below Wilkesboro

the hills in many places close in on the river and cut off the flood plain, but where the flood plain is present its width ranges from 200 to 400 yards.

Where the flood plain is broad the narrow notch or shelf representing the ordinary flood plain changes to a flood-scoured, sand-covered tract, 25 yards or more in width at first, but wider farther down, which has been formed by flood currents cutting away the ordinary flood plain. These sandy wastes, which are especially likely to occur on the inside of bends, even those of very slight curvature, are generally 100 to 300 yards long, and rise either just to ordinary stream level or 1 foot to 3 feet above it. Along the edge away from the river the bordering flood plain is being undercut, so that the width of the scoured belt is evidently becoming greater. The residents of this region say that much of this damage has been done in recent years and that it is steadily increasing. In a few places sand has been spread over the fertile bottom lands, as, for example, just east of Elkin. More commonly, however, the floods cut the rich alluvial deposits away and deposit sand in their place. The river is building sand bars behind projecting ledges or rock or chance obstructions on the concave side of curves and is evidently overloaded with waste, the source of which is, as is equally evident, the eroded slopes of its upper tributaries.

At a number of places the river flows across ledges of hard igneous rock, through which it is slowly but persistently cutting its way. The shoals and rapids that have developed at these places furnish many opportunities for power development. Storage basins constructed along the stream, however, would doubtless as quickly fill with sand and silt as do those on the similar streams southwest of the Yadkin.

The valley walls are as a rule low and retreating and join the flood-plain surface at their base in very gently rounded curves. The valley sides and the upland beyond are generally 60 to 75 per cent cleared, and half of the cleared slopes show gullying of the long, narrow, shoestring type. The width of the river varies greatly. Where it is widest the flood plain is 3 to 5 feet; where narrow it is 8 to 12 feet above ordinary stream level. A few miles above Shoals, on the north side of the river flood plain, a projecting knob 250 yards long and 30 yards wide rises 40 feet above flood-plain level. It was doubtless formed as an island when the stream flowed at the level of the old terrace mentioned, and as the river cut down to the present level it maintained both channels nearly until the present day before the left-hand channel became filled. The interval at this fossil island between the old terrace level and the present flood plain is 70 to 80 feet, and much of the terrace scarp has long been cleared, and parts of it are now eroded.

REDDIE RIVER.

For several miles from Wilkesboro Reddie River flows in a narrow trench cut 150 to 175 feet beneath the Piedmont level and has no flood plain, but above this stretch, up to a point a mile below Reddie River post office, narrow bottoms, consisting generally of hanging or beveled plains, occur here and there. In this distance 20 per cent of the low slopes on each side of the stream have been cleared. The hillsides erode as usual where the soil is of clay but are well preserved where it is stony.

From Reddie River post office up to Whittington the bottoms are fair to good in quality and include a narrow, washed cobble or gravel zone near the stream. Up North Fork the hillside clearings extend 100 to 200 yards up the slope and are not washing. Up Middle Fork there are narrow bottoms for 2 miles, above which the valley shuts in for some miles, but in the upper 4 miles the stream has a shifting channel and narrow beveled torrent plain. This torrent plain and the lower hill slopes are cleared. The soil is stony and is not eroding except where the slopes are steep.

For a number of years lumbering has been active on Reddie River well up to its head, and much of the best timber has been removed. It is hauled by wagon to Wilkesboro. Along the crest of the Blue Ridge 20 to 35 per cent of the drainage area is cleared and much the larger part of it is in grass.

MULBERRY GAP TO WILKESBORO.

Near Mulberry Gap 25 to 30 per cent of the Blue Ridge crest is cleared and in grass. The loose, porous soil generally contains many small stones and erosion is at a minimum. On the south side of the ridge the soil is poor and the higher slopes are uncleared. The timber is of medium quality and much of it has been cut by small mills and hauled 25 miles or more to Wilkesboro.

Up Mulberry River the bottom is a torrent plain which is narrow in some places, but in others attains a width of half a mile. It has a fairly good sandy soil underlain by cobbles and is in moderately good condition as regards erosion. The clearings on the lower upland slopes are cut into gullies or show sheet erosion as they grow old and include many areas of worn-out old fields.

NEW RIVER BASIN.

GENERAL FEATURES.

The New River basin was examined in detail south of Fries and Galax, Va., and the river itself was traversed down to the point at which the New River branch of the Norfolk & Western Railroad leaves it, just south of Pulaski, Va.

New River rises near Blowing Rock, N. C., and flows with many meanders northeastward over an air-line distance of 90 miles to Radford, Va., where it turns to the northwest, cuts through the mountains of Virginia and West Virginia, and as the Kanawha finally joins the Ohio.

Its basin is bounded on the southeast by the crest of the Blue Ridge and on the northwest by the basins of the Watauga and Holston. The upper end of the basin, which lies on the Asheville Plateau level, here 3,000 feet above sea level, narrows to a point at Blowing Rock, N. C.

From many points along the crest of the Blue Ridge the valley of New River appears as a great ampitheater-like basin, walled in by high mountains on the south, west, north, and northwest. Within this basin New River and its tributaries, like the streams in the Asheville region itself, have incised their channels in narrow, steep-sided trenches, varying from a shallow groove to a gorge 200 feet in depth, and above the general surface there rise many residual mountain masses, such as Bald Knob, Peach Bottom Mountain, Nigger Mountain, and others, most of which reach elevations of 4,500 to 5,500 feet, and, consequently, tower some 1,500 to 2,500 feet above the plateau level.

From a short distance below its head down to the point at which it enters a limestone valley near Ivanhoe Furnace, Va., New River has cut down through crystalline rocks so rapidly that its valley has not had time to weather back appreciably, and very little flood plain has been developed. Similar conditions prevail on practically all of its tributaries, so that stream slopes are usually steep and are mostly wooded, and flood plains are narrow or absent. The amount of waste carried by the river and its tributaries is relatively small, except in the Independence region, where erosion of cleared slopes is more active than elsewhere. Outside of the Independence area the streams are able not only to carry away all of the waste furnished from their slopes but to vigorously erode their channels besides. They flow on bare rocks and have sufficient fall to remove rapidly all flood waters.

The most striking feature in the basin is the activity in lumbering which has resulted from the recent extension of a railway into it. Small portable sawmills have been located in even the most remote mountain coves, and lumber, tanbark, and crossties are hauled as much as 30 miles over mountain roads that are in many places execrable. Those who are engaged in the industry get for their product prices that amount only to low wages for themselves and their teams. They practically give their timber away, cut their roads to pieces in hauling it, and by its removal hasten the erosion of their steep mountain slopes and narrow flood-plain areas.

The climate of the region is favorable to the growth of grass, which readily sets on cleared land, and the region in general resembles the upper Holston Valley. Some corn and small grain are raised, but grazing is the chief industry of the region and much of the cleared land is kept in grass, which is used for pasture or cut for hay. The cleared slopes when held in grass do not erode, and in this respect also the region is comparable to the Holston. Erosion, however, is by no means entirely absent, for some slopes have been cleared that are too steep for even grass to hold, and in places the steep land has been unwisely cultivated in corn and grain instead of being put in grass. Such cultivated lands erode readily and are visible at distances of even 10 to 20 miles as bare red areas on the hillsides.

DETAILS OF CONDITIONS.

Galax is situated in an expansion of the valley of Chestnut Creek, where there is a wide flood plain, bordered on the west by a broad 50-foot terrace on which most of the town is situated. The land along the creek above Galax is for the most part cleared, and the lower slopes as well as the bottoms are nearly all in grass and are in good condition as regards erosion.

Below Galax, Chestnut Creek has scarcely any flood plain, and its immediate valley walls are so steep that they are largely wooded.

On the uplands of Wards Mill Branch the cleared area amounts to 60 per cent or more, much the larger part being in grass. Thence eastward to Piper Gap the cleared area is confined more largely to the vicinity of the streams and comprises only about 3 per cent of the total area. In no place was active erosion in progress, though in a few places small areas of especially steep slope had been stripped of their sod. The rocks of the region are mostly a mica gneiss which has weathered deep, making a soft loamy soil. In a few places the underlying rock is a hornblende schist that weathers less deep and produces a more compact clayey soil, which would erode readily were it not for the fact that it usually contains many small scattered pieces of the rock that prevent rapid erosion.

The southern slope of the Blue Ridge near Pipers Gap is very steep and is well wooded. Northeast of the gap, on the higher slopes along the ridge crest, there are some clearings which are in good condition because they are kept sodded.

Above Lambsburg the streams show narrow torrent flood plains, bordered by old beveled terrace scarps that range in height from 40 to 100 feet. The streams are damaging their flood plains and occasionally destroy crops.

From Lambsburg to Low Gap the uplands are usually rough and poor, and only a small part of the area is cleared. The small streams are bordered by narrow flood plains, which are usually farmed and are in good condition as regards erosion. The best timber has been cut out and in places forest fires have followed the cutting and injured the remaining growth.

On the head of Fishers River there is much good bottom land, and nearly all of the uplands near it are cleared. The land is prevailingly stony, bears good crops, and does not wash easily. On the higher southern slopes of the Blue Ridge 30 to 40 per cent of the area to the east of Low Gap is cleared and is largely in grass. Lumbering on the head of this river has been active during the last 10 years, and the farmers on its bottom lands claim that floods have greatly increased in frequency, height, and destructiveness during this period.

A very large portion of the Blue Ridge crest from Low Gap southward to Roaring Gap is forested, and the soil, which is derived from mica schist, is, as a rule, poor and loamy. In places the forest is poor, but in the more sheltered northern coves there are some good hardwood areas and along the small streams some hemlock and white pine. West of the range the slope is exceedingly gentle, and in many places more than half of the area is cleared. As seen from a point on the ridge just south of Low Gap, 50 per cent of New River basin seems to be cleared and 45 or 50 per cent of the visible slopes of the high bounding ridges to the south and west seem also cleared. These mountain slopes appear not to have eroded as easily as the slopes from the dissected plateau level down to the present stream channels.

Indeed, in the entire range of vision, embracing an angle of 180° and extending for a distance of 10 to 20 miles, comparatively few eroded areas were visible. Some erosion was manifest on the slopes of Bald Knob, Fender Knob, Buck Mountain, Bullhead Mountain, and Peach Bottom Mountain, but in any one of these places a few acres would include the reddened eroded areas. Later detailed examination showed this apparent absence of erosion to be as characteristic of the New as of the Holston basin and to be in marked contrast to erosion conditions farther south, as, for instance, in the French Broad or Nolichucky basins.

The land on Big and Little Pine creeks is poor and only 10 to 20 per cent of it is cleared.

On Laurel Branch the valley floor and lower slopes are nearly all in grass. On the ridge near Roaring Gap 15 to 20 per cent will include the cleared area, practically all of which is sodded.

From Roaring Gap to Sparta the stream valleys as well as much of the plateau surface are in meadow, and in some places the steep slopes on the residual peaks show red from gullying.

Between Sparta and Whitehead more than half the area is in excellent grass and lands are worth more than $100 an acre.

On the higher slopes on the east side of Peach Bottom Mountain badly eroded areas were seen in three places. These lands were too steep to be cleared under any circumstances and should have been left permanently in forest.

From Whitehead to Laurel Springs the land is largely in grass and in good condition, much as it is between Sparta and Whitehead.

From Laurel Springs west to New River 40 per cent of the land is in grass and erosive effects are prominent at only two points, which are southwest and west of Ore Knob. The erosion at these points and immediately around the copper mine at Ore Knob was probably started as it has been at Ducktown, Tenn., by the killing of the vegetation by sulphuric acid fumes from the roasting heaps and smelter. As the smelter has not been in operation for several years, new areas bare of vegetation are not developing, and only an occasional old area tends to enlarge. Throughout this region of prevailing meadow land the grass grows along the small streams down to the water's edge, so that their banks are well protected and the position of their channels is fixed. The streams themselves are limpid and clear, and flow usually with rapid currents over clean-washed gravel and cobbles. The contrast between their condition and that of the muddy, overloaded streams farther south is striking.

East and south of Jefferson the bottom lands along New River vary greatly in width. In some places they are absent; in others they form a strip 200 yards wide. These bottoms are kept in grass. Floods are reported to do little or no damage either to land, bridges, or crops. The uplands are more than half in forest and as a rule are not eroding. The eroded areas in this region are confined to the very steepest cleared slopes, and even such areas are reported to be decreasing in size during recent years, since the farmers have been practicing a better system of agriculture, whereby the raising of corn and small grain is being transferred more and more to level bottom lands and the steep hill lands are being sodded for meadow or pasture. This change has been accelerated by increases in the price of stock. Much of the best lumber has been cut from this region and hauled a long distance to the railroad, either at Wilkesboro on the east or to some point near Butler, Tenn., on the west.

From Jefferson to Beaver Creek the higher hilltops are largely wooded, but the rest of the country is three-fourths cleared. Between Beaver Creek and Elk Crossroads the cleared land is in much smaller proportion and is confined to the stream valleys and lower hill slopes. Its condition is satisfactory, though some effects of erosion appear just north of the crossroads.

At Elk Crossroads three-fourths of the region is wooded, though in some places steep slopes are cleared to the tops of the ridges. The soil is stony and most of it is kept in grass, so that injury from erosion is much less than would be expected from the steepness of the slope. Flood damages along the streams are practically absent.

From Elk Crossroads westward to Snake Mountain gap four-fifths of the area is wooded and the cleared slopes do not show conspicuous erosion damages. Lumbering has been active for a number of years and much of the best timber has been removed.

The middle and upper slopes of Snake Mountain and the neighboring higher knobs are almost entirely wooded.

On Hoskins Fork a cleared flood plain extends from about 2 miles below its head down to its mouth at Sutherland, and much the larger part of the slopes and ridge crests on each side are also cleared. One of the best grass areas in the entire New River basin is found on this creek about Sutherland.

From Sutherland to Creston the lower slopes are cleared, and the higher are forested, much as in the area just described.

The river from Creston to the mouth of Rich Hill Creek has a broad, shallow channel, bordered by a zone of cobbles, and very little flood plain. The basin of Rich Hill Creek was being actively lumbered in 1907. About 50 to 60 per cent of it is cleared, and in some places the steepest slopes show bare areas of red clay. These eroded areas are said to be decreasing since better care has been taken of the land.

It is claimed that in three or four years these "galls," as they are called, may be reclaimed by covering them with leaves and brush and thus checking further erosion until vegetation may once more take hold.

On the head of Rich Hill Creek and in the region to the northeast, across the basins of Little Horse Creek, Windfall Creek, Horse Creek, and Holton Creek, the rocks change to an epidote-bearing granite or to highly acidic eruptives that weather into a more impervious clay soil than the gneiss and schist farther east and south and so are more inclined to erode where steep slopes are cleared and left bare of grass. These rocks produce, however, a richer soil, and the growth of grass, to which most of the cleared area is devoted, is more vigorous than on the poorer soils and largely prevents erosion.

The timber on the mountains at the heads of these creeks has been purchased by lumber companies within the last few years, most of it in fee simple, at prices reported to average $15 an acre, though recent purchases had been made at $18 and some even at $25. Most of this land when cleared sets naturally in grass and makes most excellent grazing land, so that its agricultural value is high and justifies the prices that have been paid for it.

From Holton toward Mouth-of-Wilson the ridges become lower, the slopes gentler, and the bottoms broader, the amount of cleared land increases, and though grass still predominates the proportion of cultivated land becomes greater eastward until, west of Independence, the area of cultivated land exceeds that of grass land.

The rocks of the region are chiefly granitic, with greenstone and other schists and some acidic intrusives in subordinate amounts.

At Mouth-of-Wilson there is no flood plain along the river. The small creeks have narrow flood plains which are occupied very largely by gravel and cobble zones, the channels themselves being well filled with sand.

Near Independence granite becomes abundant and produces by its decomposition red clay soils. The steep slopes show a tendency to rapid erosion. The granite is poor in mica, however, and gullies do not become deep and then undercut and cave, but are long, narrow, and sharp-bottomed, and extend radially down the steep slopes.

From Mouth-of-Wilson eastward to Independence more hillside erosion was observed than in any part of the New River basin thus far described. The effects of erosion were especially prominent in the basin of Fox Creek, on the west side of Bridle Creek, and on some of the southern spurs of Buck Mountain, as well as just north and again just southeast of Independence. Erosion is reported to be worse in the eastern side of Grayson County than in the western, because the eastern part has been settled and cleared longer, and as the lands have grown old the tendency to erosion has increased.

From Independence to Sparta 50 to 60 per cent of the area is cleared. Much of the soil is a red clay derived from granite, and in the first few miles south of Independence, and again in the 2 miles just south of New River, the hillsides were badly eroded by parallel gullies of the deep, narrow, granitic-soil type. All of these lands have been cleared for years, and some of the erosion is the result of neglect, but in other places the slopes are too steep to be cleared and cultivated with safety. Between Sparta and Galax the steep slopes are mostly on granite rocks, and the fields, except where freshly cleared, are usually radially scored with sharp-bottomed gullies. Where the rocks are of diabase or other basic igneous rock erosion is much less active. About half of the land is cleared; three-fourths of the cleared area is in grass and the rest is principally in corn and buckwheat.

Little River near Sparta and downstream to its mouth flows in a very narrow trench cut 100 to 200 feet below the plateau level, in few places wide enough to accommodate both the river and a flood plain. The slopes from the plateau down to the stream are usually very steep and in most places are uncleared.

MONONGAHELA RIVER BASIN.

GENERAL FEATURES.

In March, 1907, an unusually high flood on the Monongahela inflicted great loss at Pittsburg and made it seem desirable to study conditions in the entire Monongahela basin and determine, if possible, the causes of the damage wrought. This study was made late in the summer of 1907.

The Monongahela rises in northern West Virginia and flows northward to join the Allegheny at Pittsburg, thereby forming the Ohio. The upper and middle parts of its drainage basin lie mainly in northern West Virginia, although a bit of its eastern margin is included in the extreme western end of Maryland; the lower or northern part of its basin is in Pennsylvania. The basin is 150 miles in length and averages 70 miles in width. Much of its area is a plateau that stands 1,500 to 2,000 feet above sea level, though what is presumably this same plateau rises to an elevation of over 3,000 feet in some places, as, for example, near Davis, W. Va. The eastern rim of the basin has an average altitude of 3,000 feet in Pennsylvania and Maryland, but in West Virginia rises rapidly southward to elevations of 3,500, 4,000, and in places even 4,800 feet above sea level. The rim in its southeastern portion ranges in altitude from 4,000 to 4,600 feet, but along its western edge declines abruptly to 3,500, 2,500, 1,800, and farther north sinks to an altitude of about 1,600 feet, an elevation which it retains in its middle and northwestern part.

The rocks of the entire basin are conglomerates, sandstone, shale, and limestones, and nearly all are of Carboniferous age.

In the eastern part of the basin in West Virginia, Maryland, and Pennsylvania these rocks have been folded into long, narrow anticlines and synclines whose crests have been planed off by erosion, which has laid bare the edges of beds that vary much in their resistance to erosion. The harder conglomerates and sandstones form ridges; the softer shales and limestones have been eroded and form the valleys. The topography is consequently characterized by long, parallel ridges and valleys which trend northeast-southwest. The parallelism of the eastern members of the Monongahela drainage system is due to the folding and the subsequent differential erosion of the hard and soft beds. The rough topography, the narrow stream gorges, and, in places, the stony surfaces, are due to these same causes.

In the middle and western parts of the Monongahela basin the strata lie nearly flat and are composed largely of shale, but include some sandstone. The surface has been so deeply and so generally cut by the numerous branching streams that the slopes are nearly everywhere steep, though, as a rule, they are precipitous only where, for short stretches, heavy sandstone outcrops in a valley wall. The streams have cut to depths of 300 to 500 feet, and most of them are still actively down cutting, but are doing comparatively little widening, so that they flow in relatively narrow valleys, though on many of them there are narrow flood plains.

YOUGHIOGHENY RIVER BASIN.

The largest eastern tributary is the Youghiogheny. The upper portion of this river, in Maryland, has recently been described in a report on Garrett County, published by the Maryland Geological Survey, and does not differ essentially from that of the Monongahela, in the same State, for the topography, soil, amount of cleared land, mining development, and other features are essentially the same.

CHEAT RIVER BASIN.

The next tributary of the Monongahela west of the Youghiogheny on the eastern side of the basin is Cheat River. Shavers Fork of Cheat River rises in Pocahontas County, W. Va., and flows northeastward between two parallel mountain ridges, whose elevation in places reaches 4,000 to 4,800 feet. Its basin is 50 miles long and only 4 to 6 miles wide. Between ridge crest and streamway the difference in elevation on Shavers Fork is generally 1,000 to 1,500 feet, and its valley slopes are therefore in places exceedingly steep. Most of the country is rough from the outcrop of resistant sandstones, and the area of cleared land on the slopes is small. Along the stream there is almost no flood plain. The basin is largely in timber, nearly all of which has been sold to lumbermen. Some of it has already been cut and the rest is being cut at a rapid rate.

On Shavers Ridge there is a considerable area of good cleared land, which is largely in grass and is not eroding.

On Cheat Mountain, west of Shavers Fork, there is much rough land, but 20 or 25 per cent of the ridge is in grass. The timber either has been cut or is being cut rapidly.

The basin of Dry Fork of Cheat River, though rough, includes narrow flood plains and fertile lower slopes that have been cleared and now suffer erosion, especially where the soil is sandy. The stream frequently cuts to pieces or covers with sand all of the flood plain within its reach, and in July, 1907, swept away every bridge on the Dry Fork Railroad. Most of the timber has been removed, and in places 25 per cent of the slopes have been cleared.

Much of the western slope of Allegheny Mountain is rough and in brush, the timber having been cut. Only 5 or 10 per cent of its area is farmed, and this part is mostly used for grazing. One-third of the crest of Rich Mountain near its south end is in grass; the rest of it is rough, but has some good timber left, some of which is still in small holdings.

Laurel Fork has a rough basin, all of which is in timber. It was being logged in 1907.

Glady Fork has some good farm lands near its head, but the rest of its basin is rougher and the timber in it was being cut.

Middle Mountain has some fertile land, and 25 per cent of it is cleared and is principally in grass.

Blackwater River flows in a deep gorge below Davis and is largely in brush and swamp above Davis, except in Canaan Valley, which is level and fertile and is nearly all well sodded. All of the Blackwater basin except its lower part has been thoroughly lumbered and then burned over, so that in many places the bare rocks are exposed and scarcely anything but briers and fire-scald cherries have since been able to take hold. It will be years before a commercial forest can be started and centuries before the magnificent hemlock, spruce, and pine that once covered it can grow again.

The plateau on either side of the gorge on the lower part of the river is still forested, and many of the hemlocks show between 300 and 400 rings of annual growth. Logging railroads have recently been built into this magnificent forest and it is being rapidly cut and will soon be gone, as the forest about Davis has already gone.

Near Parsons and down to St. George there are some broad bottoms along the river, but they are rather too sandy for grass and are planted in corn. From St. George down practically to its mouth, just beyond the Pennsylvania line, the Cheat flows in a wild, rock-bound gorge that is 1,000 to 1,200 feet deep. In a few places, just before crossing into Pennsylvania, it has developed small flood-plain areas, but they are relatively unimportant.

On the west slope of Backbone Mountain, north of Blackwater, the timber remains and is held by a lumber company. There is some timber left on Horseshoe Run and Mill Run. The soils in the basins of these creeks, as well as in those of Clover and Haddocks runs, on the opposite side of the river, are poor but are largely cleared. The soils of the narrow flood plains along the smaller streams are of medium quality only. In July, 1907, however, nearly all of these small bottoms were destroyed by a flood and the crops on the rest of them were ruined. The loss to farms and roads in Tucker County by this flood is estimated at $30,000. The West Virginia Central's roadbed was so badly damaged that no trains ran for a week

along the Blackwater gorge, and the Dry Fork Railroad was some two weeks in rebuilding the bridges and roadbed swept away.

On the east side of Cheat River, around Aurora, in Preston County, about a third of the area is cleared. About half of this is in grass and the rest in corn, potatoes, and oats. Most of the remaining two-thirds has been lumbered and then burned over and is now in brush. The steepest slopes facing the river and along the larger tributaries are either rough and uncleared, or, if cleared, are in grass.

From the Baltimore & Ohio Railroad northward on the east side of Cheat River there is much good land away from the river front, and a very large proportion of it is cleared and used for grazing. The soil does not wash except along the steep river slopes. During the 1907 floods the only damages sustained were the destruction of small bridges along a few of the streams in Portland district of Preston County. The more level parts are almost entirely under cultivation or in grass. Erosion is not serious and floods have not greatly damaged lands or property.

The eastern edge and the central part of Grant district, which extends northward to the Pennsylvania line, are largely cleared; the western portion is bordered by Chestnut Ridge. The lands here are poor and rough, with much timber, most of which is in the hands of lumber companies.

On the western side of Cheat River, as it flows through Preston County, lands back from the river front are generally good and are largely cleared. Along the Laurel Hills, however, in the south end of the county and along the northwestern border near the Cheat, the lands are quite rough, owing to the influence of the Cheat Ridge uplift. Near the river there is a larger proportion of forested land than elsewhere, but most of the timber has been removed.

TYGART VALLEY RIVER.

From Elkins to the head of the river the basin of the Tygart Valley is very fertile and is for the most part largely cleared. Lands are worth $50 or more per acre. Much the larger part of the area is in grass, but corn enough for home consumption is raised. Floods, as a rule, do no damage to the lands, but in 1907 they destroyed some 10 per cent of the hay crop. The previous flood of similar height to that of July 17, 1907, was in 1896. The 1907 flood destroyed many logging roads and inflicted a damage of $150,000 on the people of Randolph County.

Just below Elkins, on Leading Creek, a tributary of Tygart Valley River from the northeast, are some relatively broad and fertile bottom lands, practically all of which are in grass. In places the lower hill slopes have been cleared, but some 90 per cent of the upland is in forest. The soil is poor; the timber is scant and the best of it has been cut. Farther north, on the east side near Meadowville and on Teter Creek and Brushy Fork, there are some excellent grass lands.

Along the Big and Little Sandy bottom lands and uplands have been largely cleared. The flood of July, 1907, was especially destructive both to the lands and to the crops along these creeks. The basins are long and relatively narrow and the flood swept down them with great violence. The rainfall in this region seems to have been heavier than anywhere else, unless at the very head of Buckhannon River, near Pickens.

Three Fork basin has, as a rule, a poor soil, some 20 per cent of which has been cleared and is about evenly divided between grass and cultivated crops. Lying along the main line of the Baltimore & Ohio Railroad, this basin has been thoroughly lumbered and a large part of it has since grown up in brush. Floods in July, 1907, were very high on this creek and tore up many of the roads, but caused greatest loss to the Baltimore & Ohio Railroad, whose tracks down near the stream level were much damaged.

In Marion County, on the east side of the river, the bluffs and slopes for a little distance back are usually steep and uncleared, but farther away from the river the country becomes better and 50 to 75 per cent is cleared. Two-thirds of the cleared area is sodded. Practically no commercial timber is left.

On the Tygart Valley River itself the broad bottoms disappear in a few miles below Elkins, and the river flows practically to its mouth near Fairmont in a narrow, steep-sided channel, cut 300 to 400 feet below the general level, with no flood plain of any importance. The walls of the river valley are cleared where they are composed of shale, but are rough and rugged where heavy sandstones outcrop and are there forested. The lumber has been cut and in many places mine props have also been taken. Farther back from the river on both sides the country is less rugged and a large proportion is cleared and in grass.

Middle Fork drains a rough region just west of the upper part of Tygart Valley River, to which it is tributary. There are no bottom lands along the stream, and as the rocks in its basin are chiefly sandstones the soil is poor. It is reported that not more than 5 per cent of its area is cleared. Much of the timber has been removed and active logging is now going on where any salable material is left. The land has not been damaged by erosion or floods.

On Rich Mountain, which forms the dividing ridge between Middle Fork basin and the main Tygart basin, the soil is derived from a conglomerate and the lands are rough and poor and very little farmed. On the south end much of the timber remains, but on the middle and northern part it has already been cut and the region is growing up in brush.

Buckhannon River is the next tributary of Tygarts Valley west of Middle Fork. The upper part of its basin is made rough by the sandstones and conglomerates into which the streams have cut sharply along the river and on its principal tributaries. Flood plain is either lacking or is sandy, stony, and of poor quality. On the headwaters in Randolph County not more than 15 per cent of the area is cleared. The remainder has been heavily forested, but in 1907 lumbering was being actively carried on. At Pickens and elsewhere there are large lumber mills, and back along the smaller streams there are numerous small portable mills. Where the land is not too rough it sods well when cleared and makes excellent pasture. No damage has been done by erosion, but the flood of July 17, 1907, greatly injured or destroyed whatever was in its reach, the principal loser being the railway company, whose tracks for the entire length down to Buckhannon run close by the river bank. At many places the roadbed was badly washed. Several of the logging tramways in the upper part of the basin were also damaged by the flood, the losses ranging from $10,000 to $30,000.

Farther down the Buckhannon, in southern Upshur County, where the sandstones largely disappear and shaly soils predominate, 35 per cent of the land is cleared, and the remainder has been lumbered—some of it twice. Northward the proportion of cleared land increases, and near Buckhannon and in the northern part of the county on Turkey and Hassicks runs 75 to 95 per cent of it is cleared, the proportion being larger in the western part of the county than in the eastern.

In the western and northern parts of Upshur County red shales are in places abundant, and where on steep slopes are likely to cause landslips that may do considerable damage to lands, roads, or even railway tracks that happen to be built on them. Where such areas are cleared they are kept in grass as much as possible. The streams in this northern and western part of the county have, as a rule, narrow, sodded flood plains, and flood damages during 1907 were confined chiefly to the growing grass and to the steep red-shale surfaces. No bridges were lost along the streams.

For several miles below Buckhannon the river is bordered by some beautiful fertile flood plains; it then enters a narrow trench and thence to its mouth has scarcely any flood plain, and the valley slopes are so steep that they are practically uncleared. Some of its tributaries, however, such as Pecks Run and Big Run on the west side, have excellent meadows, and their uplands are 90 per cent or more cleared. On the east side of the river the country is rough and poor, and comparatively little has been cleared. The merchantable timber has been removed and much of the land is in brush.

In the region west of Grafton the surface rocks are largely shales, and 60 to 90 per cent of the area is cleared; perhaps three-fourths of the cleared area is sodded. At no place was erosion conspicuous, though its work was apparent in some places, especially on red shale slopes where the land is cultivated. Floods during 1907 had damaged growing crops, but had improved rather than injured lands. No bridges were lost.

The valley of Lost Run is rougher and poorer and in its lower part is uncleared, though its commercial timber has been removed.

It is generally believed in this region that in basins where 60 to 90 per cent of the area is cleared and largely in sod, the floods rise more rapidly and reach greater heights now than formerly. It is also claimed that the streams in such basins show a greater tendency to go dry during summer and fall than formerly, when their basins were wooded. Many of the small streams invariably go dry at this season, and it is said that larger streams that were never known to go dry in olden times now fail entirely.

WEST FORK OF MONONGAHELA RIVER.

The upper end of the basin drained by West Fork of the Monongahela was formerly heavily timbered, but since the Sutton branch of the Baltimore & Ohio Railroad was built practically all of this timber has been removed. Three-fourths of the area is cleared and nearly all of it is in grass. The soil is derived mainly from soft shales. Somewhat lower in the basin, around Weston, 80 per cent or more has been cleared.

Almost all of the small tributary streams have narrow, flat bottoms that are in meadow and that have not been injured by recent floods. Above Weston there is no flood plain on the river, but below it in a few bends there are small areas of tillable land, and at a number of places there are terraces with flat tops and steep slopes, all of which are now high above the reach of floods. There is but little to injure along the river, and even the severest floods can do no great damage.

Along Hackers Creek there is some flood plain, and the hay and potato crops were greatly injured by the July, 1907, flood. The lands themselves, however, were unhurt. In some places red shale slopes had washed somewhat, but in no place had there been serious damage from this cause.

The rocks of Harrison County, across which West Fork flows after leaving Lewis County, consist chiefly of flat-lying shales, among which are interspersed some sandstone beds. The surface is steeply rounded, and the many tributary streams have minutely dissected it by trenches cut 400 to 500 feet below the general surface level. The narrow flood plains and nearly all of the uplands are cleared and sodded. There is only timber enough for farm use. It is estimated that between 80 and 90 per cent of the total area of the West Fork basin is in grass. The streams carry very little waste, and, as a rule, flow in deep channels. Floods escape rapidly and have caused no great damage. The heavy rains of July 16 and 17, 1907, did not extend so far west as this basin, but were confined to the Cheat and Tygart Valley rivers and their tributaries. The highest flood reported on West Fork is said to have occurred in 1888, when every bridge but one in the country was washed out and much other damage done.

The Winfield district, on the east side of the river, has more waste land than any district in Marion County. About 50 per cent of it is farmed, but much of the county is poor and rocky. On the west side 75 per cent or more is cleared, and two-thirds of the cleared area sodded. On the rest there is very little marketable timber left. The streams have at best very narrow flood plains, but since the flood of 1888 they have not been damaged by high water. The flood of July, 1907, was destructive farther east and that of March, 1907, farther north. At neither time was the river extraordinarily high in this part of the basin.

Some 15 years ago a railway was built from Morgantown up Deckers Run to Kingwood and on to Rowlesburg. The region was an almost primeval forest, densely wooded and covered with thick undergrowth, and contained many clear, cold springs. The streams rose slowly during floods and maintained a constant volume during dry seasons. With the building of the railroad, lumbering became active, and the region was soon stripped of its magnificent forests. Fires followed in the wake of the lumberman, and the dense undergrowth was also gone. The summer sun now beats down on a bare and parching land; in dry seasons the springs flow weakly or disappear, and the streams shrink to tiny rivulets. Forest and stream, cool shade, and cold spring are all gone, and the land is desolate.

At Morgantown the water supply was formerly obtained from several small streams, and although the necessity for supplementing the supply by drawing on the river has been caused by the growth of the town, the amount now available from the small streams during low-water stages has lately decreased to such an extent that it is impossible to supply from this source as large a part of the city as formerly.

On Deckers Creek in the last 40 years eight mill sites that were once profitable have been abandoned because for several months in the year the water is so low that they can not be operated steadily and profitably. The one mill that now survives is forced to remain idle a good part of the time from the same reason. Similar changes have occurred on Buffalo Creek and other streams that have been denuded of their timber to the same extent.

MONONGAHELA BASIN IN PENNSYLVANIA.

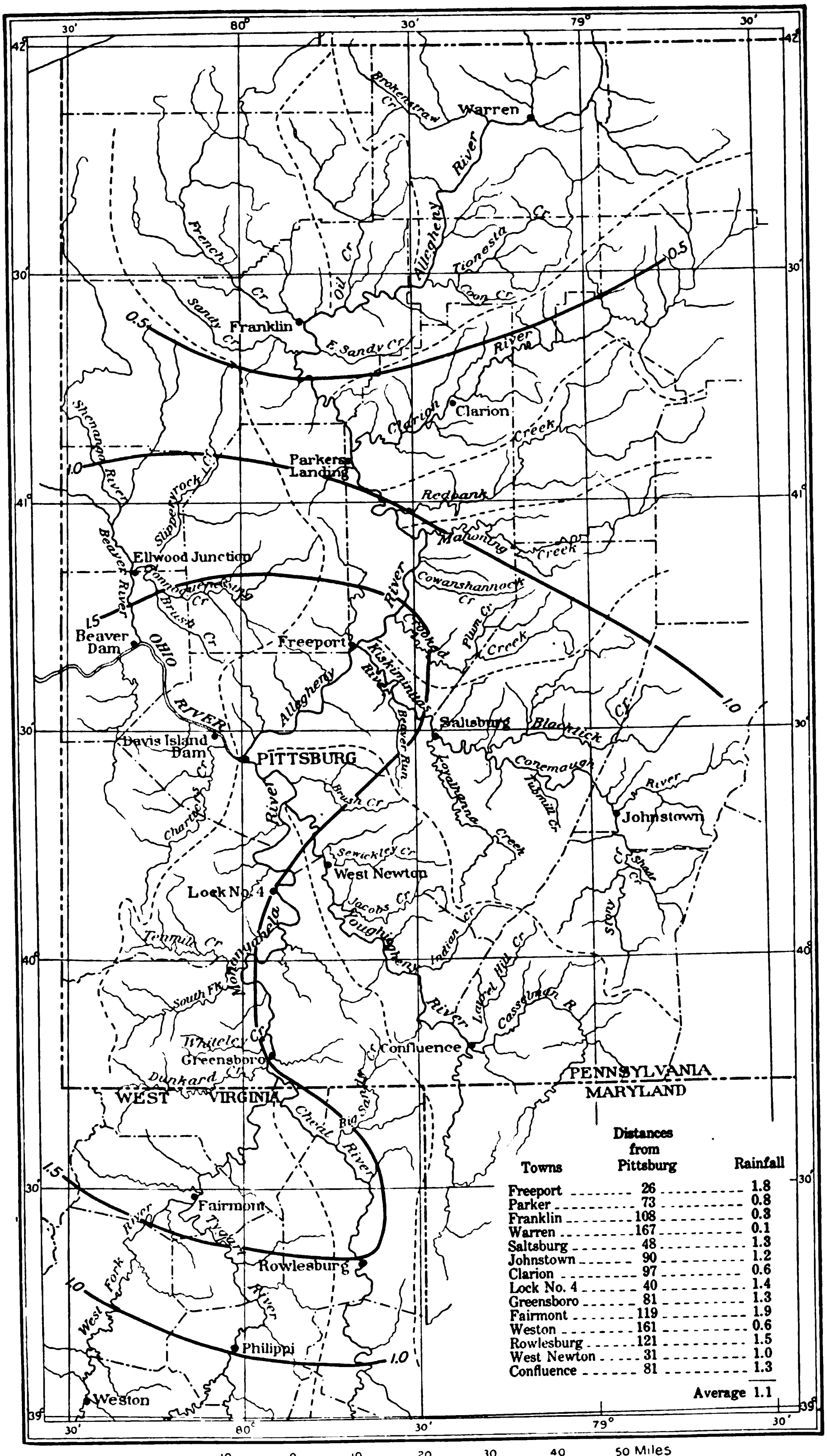
In Pennsylvania the Monongahela basin includes Fayette County, the eastern part of Green and Washington counties, the southern part of Allegheny County, and the western parts of Westmoreland and Somerset counties. With the exception of small areas in Laurel and Chestnut ridges, the rocks of the Pennsylvania part of the Monongahela basin are of Carboniferous age. On these ridges the soils are in general poor, but some small areas of limestone or calcareous shale have yielded good soils. In some places there are still areas of uncut timber, but much the larger part of the timber has been removed. Outside of these mountain ridges the surface rocks are shales, limestones, and sandstones. The limestone and the shale have yielded a soil that is generally fertile, but the soil on sandstones is thinner and the surface is generally rough. Where the streams cut through the shale the slopes, though in many places very steep, are rounded, but where they cut through sandstone the slopes are, as a rule, rough or precipitous. The steep shale slopes are mostly cleared and farmed; the sandstone slopes are generally forested.

The topography in these shales is much alike everywhere in the basin. The differences are those of degree and not of kind. As in the West Virginia part of the basin, the surface of the basin in Pennsylvania is an old plateau, now at an elevation of 1,200 to 1,400 feet and thoroughly dissected by the streams. The hill slopes are gentle or steeply rounded. The valley bottoms are not as a rule broad, but many of them meet the hills in gentle, flowing curves. In some places these hills stand up sharply; in other places their outlines are more subdued. In general cutting is deepest near main drainage ways and decreases near the heads of tributaries.

Wherever shale predominates 80 to 90 per cent of the land is cleared, and three-fourths or four-fifths of the cleared land is kept in grass. The slopes are not, on the average, as steep as in West Virginia and show less tendency to erosion, except on red shale, where the conditions in both States are the same.

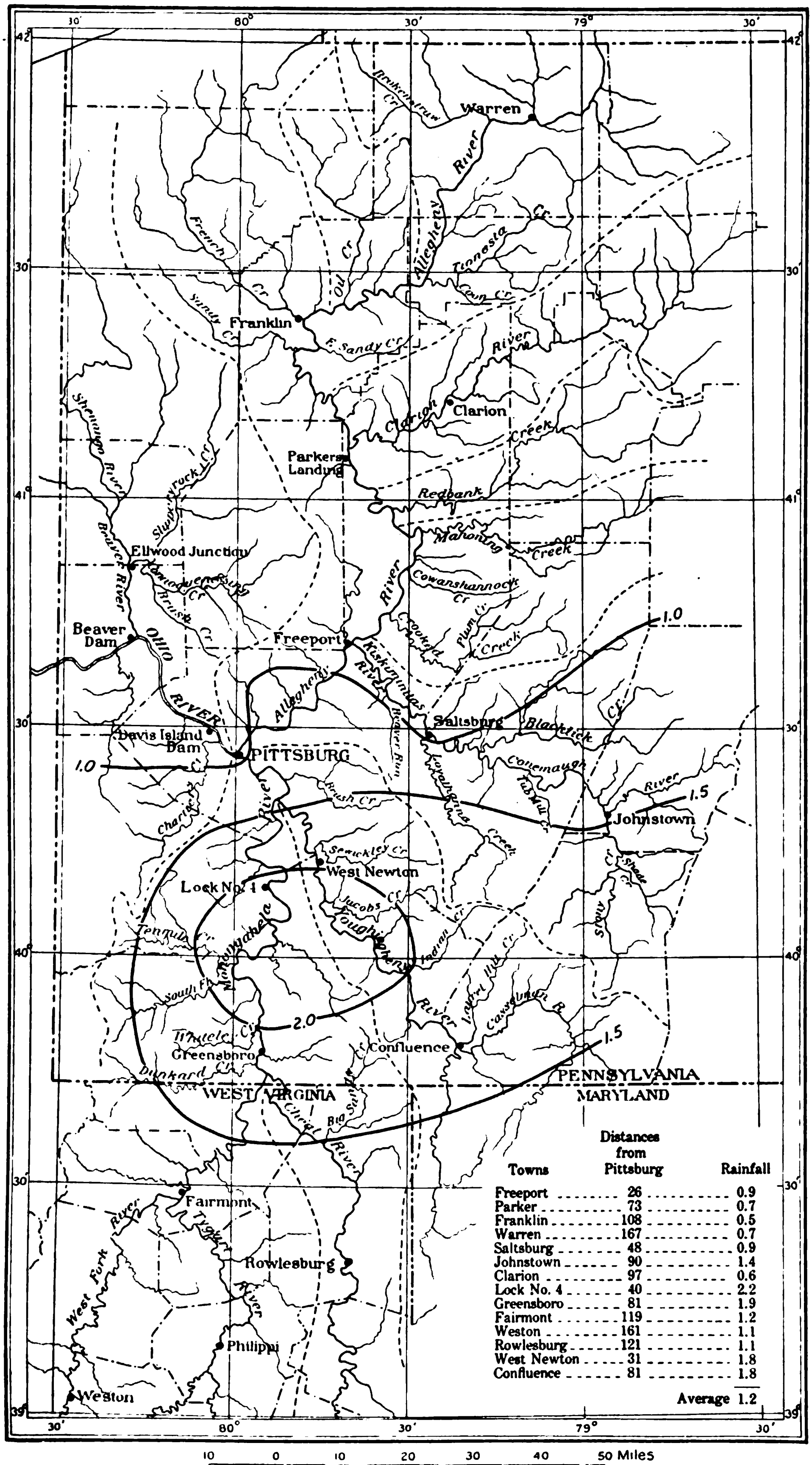
The damages from all types of erosion on hill slopes and along stream ways are unimportant, and in many places damages from floods are reported to be rare. It is the general impression that stream flow in dry seasons is now much less than formerly; and on many of the creeks the grist, saw, and paper mills of earlier days have had to shut down for want of water. Some have quit business or moved elsewhere; others have substituted more expensive but more dependable steam power. On Redstone Creek, for instance, there is only one mill left, and only one or two remain on Georges Creek. Many springs of former days have dried up and disappeared, and streams now go dry in summer that are said not to have failed in olden times.

It would seem that man has made important changes in the Monongahela basin through deforestation. The deforested land has largely been put into grass, so that erosion such as characterizes so much of the Southern Appalachians is not common. For the same reason the stream channels in the Monongahela basin are not filling with sand and gravel and causing widespread destruction of bottom lands. The cleared grassland, however, permits the rainfall to run off more rapidly than formerly when the lands were forested, so that average flood heights have become greater and flood damages have increased accordingly, as is shown by the recent disastrous flood in Pittsburg.



WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR TWENTY-FOUR HOURS ENDING 8 A. M. MARCH 13, 1907.

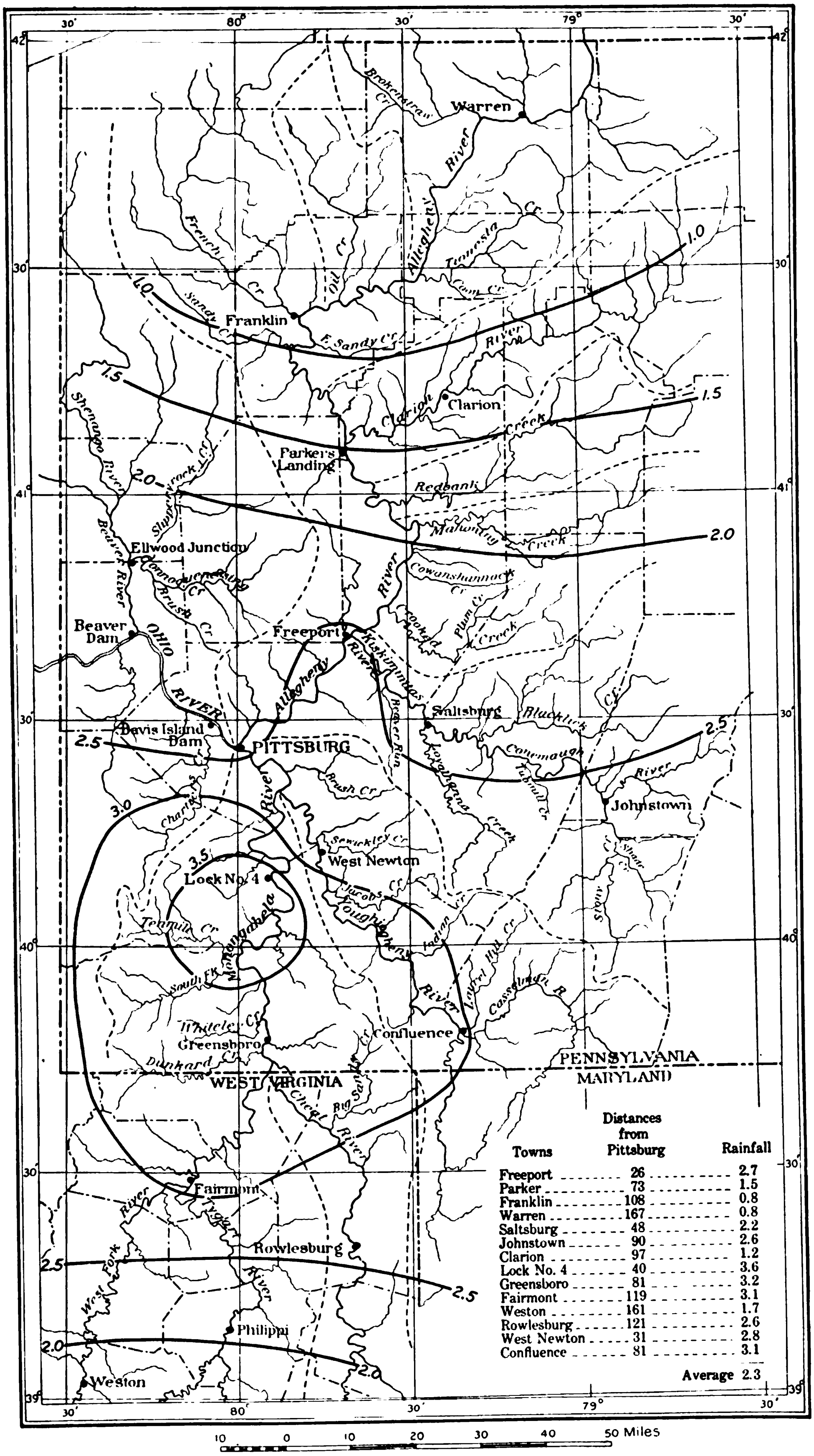
Distances in miles; rainfall in inches.



Towns	Distances from Pittsburg	Rainfall
Freeport	26	0.9
Parker	73	0.7
Franklin	108	0.5
Warren	167	0.7
Saltsburg	48	0.9
Johnstown	90	1.4
Clarion	97	0.6
Lock No. 4	40	2.2
Greensboro	81	1.9
Fairmont	119	1.2
Weston	161	1.1
Rowlesburg	121	1.1
West Newton	31	1.8
Confluence	81	1.8
Average		1.2

WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR TWENTY-FOUR HOURS ENDING 8 A. M. MARCH 14, 1907.

Distances in miles; rainfall in inches.



Towns	Distances from Pittsburg	Rainfall
Freeport	26	2.7
Parker	73	1.5
Franklin	108	0.8
Warren	167	0.8
Saltsburg	48	2.2
Johnstown	90	2.6
Clarion	97	1.2
Lock No. 4	40	3.6
Greensboro	81	3.2
Fairmont	119	3.1
Weston	161	1.7
Rowlesburg	121	2.6
West Newton	31	2.8
Confluence	81	3.1
	Average	2.3

WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR FORTY-EIGHT HOURS ENDING 8 A. M. MARCH 14, 1907.

Distances in miles; rainfall in inches.

PITTSBURG FLOOD OF MARCH, 1907.

In March, 1907, a disastrous flood in the Monongahela basin caused a loss of more than $8,000,000, chiefly in Pittsburg and its immediate vicinity. The conditions at Pittsburg preceding the flood, which reached the unprecedented height of 35.5 feet at 5 a. m., March 15, 1907, were unusual and in large measure produced the extraordinary stage and the great destruction wrought.

On March 10 and 11 there were between 4 and 8 inches of moist snow in the basin of the Allegheny and Monongahela rivers, and the temperature was 10° to 25° above the normal. Heavy rain fell in these basins on March 13 and 14 and rapidly melted the snow. The heavy rain and the melted snow at once ran into the streams, especially those in the Youghiogheny and Monongahela basins, and quickly raised the stream heights to dangerous levels. The absence of forest over so large a part of these two basins greatly hastened the run-off and raised the height of the flood beyond the stage that it would have reached under forested conditions. The great damage to property ($8,000,000) and the loss of nine lives are believed to be largely due to the deforested condition of these lands.

The weather maps reproduced in Plates XIX, XX, and XXI show that there was an unusually heavy rainfall in the two 24-hour periods ending at 8 a. m. on March 13 and 14 in the region just above West Newton on the Youghiogheny and Lock 4 on the Monongahela. The precipitation during the first of these 24-hour periods extended over the entire basins of the two rivers, but that ending on March 14 was by far the heavier and reached a maximum in the portions of the basins about West Newton and Lock 4, when both of the streams were already dangerously high from the melting of the snows and the heavy general rains of the preceding 24 hours. In the vicinity of both places 80 to 95 per cent of the country has been cleared, and this unusually heavy rainfall rushed rapidly down the steep cleared slopes to the streams and produced a local flood crest on top of the more general one which was already at a dangerous height, causing the unprecedented gage heights at West Newton on the Youghiogheny and at Lock 4 on the Monongahela. The flood crest on each of these streams some distance above these points failed by several feet to reach heights attained by previous floods.

This second flood gathered from the cleared hillsides suddenly and raised both rivers so rapidly that above this area of maximum rainfall the normal flood on each stream was checked, and for a very brief interval there is reported to have been a dead eddy in the Youghiogheny above West Newton and in the Monongahela above Lock 4.

The combination of unusual high temperature, melting snow, and heavy rainfall can not be foreseen or prevented, but when these were combined with a steep surface that had been largely denuded by man and so prepared to hurry the waters from the melting snow and the storm into the stream channels with the greatest possible rapidity the flood crest was raised to an extreme height. Had the basins of the Youghiogheny and Monongahela been more largely forested the river would probably not have reached the stage it did at Pittsburg.

It has been suggested that the encroachment on the river channel at Pittsburg was a cause of the extreme stage reached there, but when examined the encroaching structures seem too insignificant to produce this result, and it is very certain they could not cause the Youghiogheny at West Newton to rise 6.2 feet above all previous high records. It has also been suggested that the dumping of quarry refuse in the Ohio River had built out the point on its south bank just below the lower end of Brunots Island sufficiently to deflect the current flowing south of the island as it rejoined the northern current in such a way as to cause eddies that would greatly check the velocity of the Ohio and raise the flood level in Pittsburg. An examination of the quarry dump at this point showed that it was insignificant in amount and was not in proper place to produce such a result. It seems that the great flood, with its attendant damages, was due primarily to an unusual combination of natural conditions and was greatly augmented by man's agency in cutting away the forest within the watershed that received the great bulk of the rainfall.

TABLES.

The following tables give the names and location, by counties, of the streams considered in this paper. The streams are grouped to show main streams and tributaries and are arranged in classes, the basis of the classification being the character of the basins as regards timber.

Streams in timbered basins in which floods rise and fall slowly, carry little sediment, and do little damage.

Main stream.	Tributary.	County.
Nolichucky	Caney River, upper basin	Yancey County, N. C.
Watauga	No examples.	
French Broad above Asheville	Clear Creek	Henderson County, N. C.
	Crabtree Creek	Henderson and Transylvania counties, N. C.
	Little River	Transylvania County, N. C.
	Carson Creek	Do.
	Main stream, headwaters	Do.
	Davidson River	Do.
	Avery Creek	Henderson County, N. C.
	Mills River	Do.
Asheville to Hot Springs	Shut-in Creek	
	Little Pine Creek	Madison County, N. C.
	Big Laurel Creek	Do.
	Little Hurricane	
	Big Hurricane	
	Little Laurel Creek	Do.
	Shelton Creek	
Big Pigeon	Cataluchee Creek	Haywood County, N. C.
	Big Creek	
Little Pigeon	Alum Cave Creek	Sevier County, Tenn.
Little Tennessee	Oconalufty Creek	Swain County, N. C.
	Main stream (upper part)	Macon County, N. C.
	Forneys Creek	Swain County, N. C.
	Main stream from Bushnell to Wayside.	Between Swain and Graham counties, N. C.
	Panther Creek	Graham County, N. C.
	Sawyer Creek	
	Tuckasegee River	Jackson and Swain counties, N. C.
	Cheoah River	Graham County, N. C.
	Nantahala, tributaries	Macon and Swain counties, N. C.
Hiwassee	Valley River	Cherokee County, N. C.
	Main stream down to Murphy	Clay and Cherokee counties, N. C.
	High Tower Creek	Towns County, Ga.
	Shooting Creek	Clay County, N. C.
	Tusquitee Creek	Do.
	Fires Creek	Do.
	Brasstown Creek	Towns County, Ga., and Clay County, N. C.
Oostanaula	Jacks River	Fanin County, Ga.
	Conasauga River	Murray County, Ga.
	Clear Creek	Gilmer County, Ga.
Etowah	Main stream (upper part)	Lumpkin County, Ga.
	Amicalola Creek	Dawson County, Ga.
Savannah	Upper tributaries in North Carolina, and main stream.	Jackson and Transylvania counties, N. C.
Chattooga	Main stream at Russell's bridge	Between Rabun County, Ga., and Oconee County, S. C.
Chauga		
Tugaloo		
Saluda		
Broad	Headwaters of Tiger River	Union, Spartanburg, and Cherokee counties, S. C.
	Pacolet River	
	Green River	Henderson, Polk, and Rutherford counties, N. C.
Catawba	Tablerock Creek	Burke County, N. C.
Yadkin		
New		

Streams in cleared basins in which floods are sudden, high, subside quickly, carry much sediment, and injure their flood plains by erosion, sedimentation, or dissection.

Main stream.	Tributary.	County.
Nolichucky	Main stream, upper basin	Yancey and Mitchell counties, N. C.
	Jack Creek	Yancey County, N. C.
	Little Crab Tree Creek	Do.
	Big Rock Creek	Mitchell County, N. C.
	Cane Creek	Do.
Watauga	Elk Creek	Carter County, Tenn.
	Roan Creek (lower)	Johnson County, Tenn.
	Doe Creek	Do.
	Wilson Creek	Carter County, Tenn.
French Broad above Asheville	Caney Creek	Buncombe County, N. C.
Asheville to Hot Springs	Main stream	In parts of Buncombe and Madison counties, N. C.
	Big Sandy Marsh, Little Sandy Marsh	Buncombe and Madison counties, N. C.
	Little Ivy River	Madison County, N. C.
Big Pigeon	No examples.	
Little Pigeon	No examples.	
Little Tennessee	Savannah Creek and tributaries	
	Johns Creek	Jackson County, N. C.
	Lower course of Tiger River and Pacolet River.	Union, Spartanburg, and Cherokee counties, S. C.
Catawba	Johns River	Caldwell and Burke counties, N. C.
Yadkin	Elk River	Wilkes County, N. C.
	Main stream near Elkin	Surrey and Wilkes counties, N. C.
New River	No examples.	
Chattahoochee	Deep Creek, tributary to Soque Creek	Habersham County, Ga.
	Tributaries near Pleasant Retreat and north of Cleveland.	White County, Ga.
	Flat Creek	Hall County, Ga.
	White Creek	Do.
	Mossy Creek	White County, Ga.
	Mud Creek	
	Lower main channel and tributary creeks.	Hall, Forsyth, Milton, Gwinnett, Dekalb, Fulton, and Cobb counties, Ga.
Savannah	Popcorn Creek	Rabun County, Ga.
	Timpson Creek	Do.
Chattooga	War Womans Creek	Do.
Chauga	No examples.	
Tugaloo	Crow Creek, Little River, Panther Creek, Oostanaula Creek, main stream at Shelors Ford.	Stephens County, Ga.
Saluda	No examples.	
Broad	Tributaries between Green River and Broad River.	Rutherford and Polk counties, N. C.

Streams in cleared basins in which tributaries carry little sediment, and do little damage.

[Basins generally grassed or with porous soil.]

Main stream.	Tributary.	County.	Reason.
Nolichucky	No examples.		
Watauga	Cove Creek	Watauga County, N. C.	Porous soil and swift current.
French Broad above Asheville.	No examples.		
Asheville to Hot Springs	Spring Creek	Madison County, N. C.	Clearings in grass.
	Big Pine Creek	do	Do.
Big Pigeon	Jonathans Creek	Haywood County, N. C.	Clearings largely kept in grass.
Little Pigeon	No examples.		
Little Tennessee	Upper Watauga Creek		Steep gradient of stream.

Streams in timbered areas in which tributaries do damage to flood plains during floods following erosion caused by logging on steep slopes.

Main stream.	Tributary.	County.	Reason.
Nolichucky	No examples.		
Watauga	Do.		
French Broad above Asheville.	North Fork of Swannanoa	Buncombe County, N. C.	Slopes injured during lumbering.
Asheville to Hot Springs	No examples.		
Big Pigeon	Do.		
Little Pigeon	Do.		
Little Tennessee	Soco Creek	Jackson County, N. C.	Lumbering.
Hiwassee	No examples.		
Oostanaula	Do.		
Etowah	Do.		
Chattahoochee	Do.		
Savannah	Tallulah River basin, upper part.	Rabun County, Ga	Forest fires.
Chattooga	No examples.		
Chauga	Chauga River	Cone County, S. C	Lumbering.
Tugaloo	Brasstown Creek.		
Saluda	North Saluda (headwaters)	Greenville County, S. C.	Not given.
Broad	No examples.		
Catawba	Do.		
Yadkin	Do.		
New	Do.		

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DEPARTMENT OF THE INTERIOR

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THE TERTIARY GRAVELS

OF THE

SIERRA NEVADA OF CALIFORNIA

BY

WALDEMAR LINDGREN

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THE TERTIARY GRAVELS OF THE SIERRA NEVADA OF CALIFORNIA.

By Waldemar Lindgren.

PART I. GENERAL FEATURES OF THE PROVINCE.

CHAPTER 1. INTRODUCTION.

OUTLINE OF LATER GEOLOGIC HISTORY OF THE SIERRA NEVADA.

This report attempts to trace a part of the history of the Sierra Nevada, the great range which, for 300 miles, divides the central valleys of California from the deserts of the Great Basin. It presents an account of the Tertiary formations of that range and deals especially with the origin and distribution of the gold-bearing gravels which made these mountains one of the treasure houses of the world. It is not intended to describe the rocks and the geologic history of the pre-Tertiary periods, except in the merest outlines.

The Paleozoic and early Mesozoic seas once extended over the site where the Sierra now lifts its broad back. Toward the close of the Mesozoic era the sediments were compressed in heavy folds, and the intrusion of granitic magmas forced them upward to lofty summits; after the intrusion the fissures and joints of granitic rocks and altered sediments became filled with veins and seams of gold-bearing quartz. A long period of erosion in the early Cretaceous planed down the new-born mountains. The concentration of the gold from the veins began in countless streams. Pauses in the erosion, when the topography had been reduced to gentle outlines, permitted deep rock decay and promoted the liberation of gold from its matrix. Renewed uplift quickened erosion and facilitated the further concentration of gold. Throughout Cretaceous and Tertiary time these conditions continued. Fluctuations of the western shore line at times extended the streams far into the areas now occupied by the Sacramento and San Joaquin valleys, or caused these watercourses to debouch upon flood plains reaching high up on the flanks of the range. Faulting movements, with downthrow on the east side, probably beginning in Cretaceous time, had transformed an approximately symmetrical range to a monoclinal one with steep easterly slope. Gradually the mountains were thus reduced to gentler slopes and the canyons widened to valleys. Meandering among longitudinal ridges, the rivers flowed from low divides to rolling foothills and the whole slope was clothed in the dense vegetation of a damp semitropical climate.

Long-quiescent volcanic forces asserted themselves toward the end of Tertiary time, contemporaneously with the greatest volcanic activity in the Great Basin. Rhyolite flows filled the valleys, covered the auriferous gravels, and outlined new stream courses in the old valleys. Renewed disturbance began along the scarcely healed eastern breaks, resulting in a westward tilting of the main blocks, probably combined with normal faulting. In consequence of this disturbance the monoclinal nature of the range became strongly emphasized and the streams immediately began to cut their beds deeper; they repeatedly crossed their old courses and the concentration of gold in the new canyons proceeded under less favorable torrential conditions. Eruptions of andesitic tuffs began in enormous volume and effectually buried a large number of the streams, filling their valleys to the rims. At the close of the Tertiary period a steaming, desolate expanse of volcanic mud covered almost the whole of the northern Sierra, in startling contrast to the peaceable verdure-clad hills of the Miocene. In a thousand rills the storm waters flowed down the slope, excavating rapidly in the soft tuffs.

The rills became gullies, ravines, creeks, and new master streams. Torrential grades magnified the erosive power, and thus began the canyon-cutting epoch of the late Pliocene and early Quaternary, amazing in its results, as we see them to-day. The new streams excavated sharp, V-shaped trenches in the hard rock to a depth of 1,000 to 4,000 feet below the surface of the flows. In many places the old rivers of the Tertiary period were exposed and cross sections of their valleys are now seen on the steep canyon slopes high above the present river beds. Large stretches of the old channels remained secure below their blanket of 1,000 feet of hardened volcanic mud. Wherever the canyon-cutting streams destroyed the old channels the gold in those channels became concentrated in the canyons and thousands of disintegrated quartz veins added to the previous concentrates; but owing to the steep grades of the Quaternary rivers much of the detrital material and the fine gold was swept out into the valley at the western foot of the range over alternately advancing and retreating flood plains.

The barren lava flows and the canyon slopes again became clothed by vegetation, this time of the type belonging to a cooler but still temperate climate.

Later in the Quaternary the scenes changed again. The summits became covered with persistent snows, which eventually consolidated to névé and to ice. Glaciers filled the upper valleys, but only for a comparatively brief time, disappearing rapidly before the drying winds of a warmer climate and leaving the summit region a desolate expanse of dazzling white, bare granite or reddish schists.

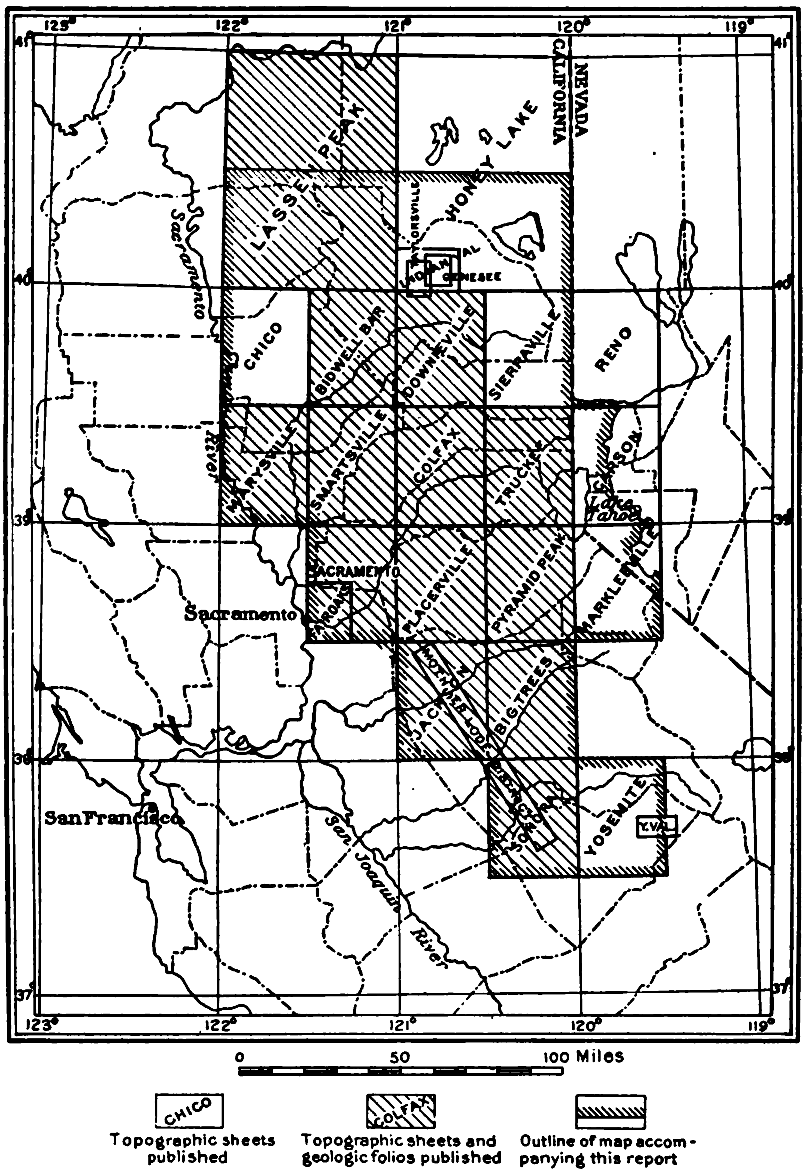

FIGURE 1.—Index map showing location of region of auriferous gravels of the Sierra Nevada.

During the last brief span of a few thousand years the Sierra Nevada has remained as we now see it, with the pleasing oak groves of the foothills, the somber giant pines of the middle slopes, and the storm-scarred hemlocks of the summit ridges.

The peace of the wilderness was interrupted in 1849. An army of gold seekers invaded the mountains; at first they attacked the auriferous gravels of the present streams, but gradually the metal was traced to the old Tertiary river beds on the summits of the ridges and to the quartz veins, the primary source of all the gold in the Sierra Nevada. (See fig. 1.) The

Tertiary stream beds—the "channels," as they are called—proved rich but difficult to mine. New methods were devised; by hydraulic mining the gravel banks were washed down by the aid of powerful streams of water, and by drift mining the bottoms of the old stream beds were followed by tunnels underneath the heavy volcanic covering.

Millions of dollars were annually recovered from these Tertiary channels, and the heyday of this industry fell in the seventies of the last century. Since then, owing to the prohibition of hydraulic mining and the gradual exhaustion of the richer channels suitable for drift mining, the industry has slowly decayed until in the year 1908 the total production of the drift, hydraulic, and surface mines of the range, for the first time since 1848, fell below $1,000,000; indeed, this figure also includes the value of the gold washed from Quaternary gravels along the rivers. Gold is still contained in the Tertiary channels; miles of them are still unworked; but the problems are how to extract it without damage to other property from the débris and how to reduce the cost of drift mining so as to permit the exploitation of the less remunerative deep gravels.

To compensate for this decay a new industry, that of dredging, has been developed along the bottom lands, where the present rivers emerge from their canyons and where fine gold has accumulated during Quaternary time on clayey or tuffaceous bedrock. During 1908 gold valued at nearly $7,500,000 was recovered by this method along the foot of the Sierra Nevada.

ACKNOWLEDGMENTS.

The work of the United States Geological Survey in the gold belt of California began in 1886 and was concluded about 15 years later. The extent of the topographic and geologic work is shown on Plate I. The examinations were begun by Mr. H. W. Turner and the author under the direction of Mr. G. F. Becker (from 1886 to 1892), and were later carried on independently, Mr. Turner mapping the north and south ends of the belt. Later Mr. F. L. Ransome contributed his share to the work in the Mother Lode folio and parts of the Sonora and Big Trees folios of the Geologic Atlas of the United States. At different times since 1884 Mr. J. S. Diller has worked in northern Plumas County and has added much to the knowledge of the gravels in this region, the result being embodied in the Lassen Peak folio and a number of other publications.

A considerable part of the study of the Tertiary gravels of the Sierra has fallen to the lot of the author because the most important gravel-mining districts were located in the area assigned to him. He has also at various times visited the principal districts outside of his area. However, a large proportion of the data in this volume have been taken from the folio texts and other publications of the geologists mentioned. The author is under the deepest obligation to these friends and coworkers, for without their help this volume would have lamentably lacked in completeness. Mr. G. K. Gilbert has very kindly permitted the publication in this volume of the results of his careful measurements of the quantities of gravel removed from the old hydraulic mines.

The accurate and detailed investigations of Mr. Ross E. Browne on the Forest Hill divide and other districts have been of the highest importance and value in formulating the conclusions in these chapters. Messrs. J. D. Whitney, W. H. Pettee, and W. A. Goodyear were the pioneers in this field and their volume on the auriferous gravels is filled with painstaking and reliable information and has been a steady companion during the writer's labors.

The determinations of the fossil plants in the gravels by Messrs. Leo Lesquereux and F. H. Knowlton have been an invaluable aid in determining the geologic age of the gravels. Prof. Knowlton has kindly contributed to this volume a chapter on the present status of the Tertiary paleobotany of the Sierra.

Heartiest thanks are extended to the many mining men who, by information and advice, have facilitated the collection of these data. Many of the photographs here reproduced were obtained through the cooperation of Dr. J. C. Hawver, of Auburn.

MAPS.

It has not been possible to provide this paper with the complete maps of the gold belt as issued by the United States Geological Survey in the Geologic Atlas of the United States. Plate I (in pocket) will serve as a general guide to the geology of the area, but it is recommended that the reader who wishes full and detailed information obtain a set of the folios relating to the gold belt, the names of which are marked on figure 1.

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CHAPTER 2. TOPOGRAPHY AND GENERAL GEOLOGY.

TOPOGRAPHY.

This report deals with the northern and larger part of the Sierra Nevada, lying between parallels 37° 30′ and 40° 30′ and extending from the Great Valley of California on the west to the escarpment facing the Great Basin on the east.

From the plains of the Sacramento Valley the first foothills of the Sierra rise rather abruptly. Except along the Central Pacific Railroad, where an easily eroded mass of granodiorite extends to the plains, the valley is bordered by a series of ridges parallel to the crest of the range and rapidly attaining elevations of 1,000 to 2,000 feet. The slope of the foothills is decidedly stronger than that of the range as a whole. At an average elevation of about 2,500 feet the main plateau or middle slopes begin, characterized by the absence of longitudinal ridges and by a gentler undulating surface, in many places reduced to an even table-land with uniform and slight westerly slope. Above the general surface of this plateau rise groups of rugged hills of more resistant material, like Sand Mountain and Slate Mountain in Eldorado County, and the Blue Mountains in Calaveras County. An average elevation of about 6,000 feet marks the western boundary of the high Sierra, a region where the plateau-like character of the middle slopes becomes obscured and finally almost completely lost. High ridges and peaks, in places longitudinally arranged, here rise above the snow line. Through all three of these divisions the torrential streams have trenched deep canyons, V-shaped and extremely abrupt in the lower two divisions, but usually more U-shaped and wider in the high Sierra. Many of the canyons have been cut to a depth of 3,000 and even 4,000 feet.

In the northern and southern parts of the area discussed the Pacific drainage reaches back to the most easterly summits of the Sierra Nevada, but in the central part two rivers of the Great Basin—the Truckee and the Carson—break through the eastern escarpment and drain considerable areas within the higher portion of the range. At the southeast corner of the area here treated the range breaks off in a magnificent slope of 6,000 feet from Mount Dana to Mono Lake, and this escarpment probably continues through the northern part of Mono County to Topaz, where it faces West Walker River, but ceases a short distance farther north. Another escarpment forming the eastern slope of the Genoa Ridge and having a height of about 5,000 feet, begins some 20 miles to the northwest of Topaz and continues due north for about 30 miles to a point a few miles southwest of Reno; another offset of a few miles to the west follows and is succeeded north of Truckee River by a somewhat lower escarpment, which is practically continuous to the north end of the Sierra, at Susanville, in Lassen County. The eastern front of the range is thus marked by four escarpments, arranged en échelon, each offset a few miles toward the west. Mr. G. K. Gilbert states that this arrangement continues south of West Walker River, at least as far as Bishop.

A more westerly eastward-facing escarpment, or crest line, is less steep. It begins a short distance south of Lake Tahoe and continues north-northwestward for about 60 miles, to an area beyond Mohawk Valley in Plumas County, where it gradually becomes effaced.

Between these two crest lines lie a series of deep depressions. The southernmost is that of Lake Tahoe, which is about 20 miles long and 10 miles wide. North of Lake Tahoe a bridge of high volcanic mountains connects the two crest lines. The next depression is Truckee Valley, and north of this another bridge of volcanic ridges connects the two divides. The third depression is Sierra Valley, a deep circular basin surrounded by andesite flows and filled with alluvium. Truckee Valley and Lake Tahoe are both drained by Truckee River, which cuts through the eastern ridges of the Sierra between Reno and Truckee and ultimately discharges into Pyramid

Lake, in the Great Basin. Sierra Valley and Mohawk Valley are drained by Plumas River, which empties into the Sacramento. Near the north end of the Sierra and within it are several smaller valleys, most of them of structural origin—Indian Valley, Grizzly Valley, Clover Valley, American Valley, Meadow Valley, and Mountain Meadows—all within the Sacramento River drainage basin.

The highest elevations are found in the southern part of the range. Mount Dana attains nearly 13,000 feet; the highest peaks of the Genoa Ridge reach 10,000 feet, but those along the western crest line fall somewhat short of this measure. North of the Central Pacific Railroad few peaks rise to 9,000 feet, and at the north end of the range the culminating points scarcely exceed 7,000 feet in elevation. The eastern base has at Mono Lake an elevation of 6,412 feet; in Carson Valley, 4,700 feet; at Reno, 4,500 feet; at Honey Lake, 3,949 feet. The western base lies about 200 feet above sea level.

THE GREAT VALLEY AND ITS EASTERN BORDER.

SACRAMENTO AND SAN JOAQUIN VALLEYS.

SEDIMENTARY DEPOSITS.

Inclosed between the Sierra Nevada on the east and the Coast Range on the west, the Great Valley of California forms a tectonic trough in which, in slightly synclinal structure, a series of sediments have accumulated, ranging in age from the earliest Cretaceous rocks to those of the present time. On the east side the valley has since the beginning of Cretaceous time been bordered by the Sierra Nevada; on the west side diastrophic processes have gradually built up the barrier of the Coast Ranges, changing the depression from a gulf of the sea to a lake and from a lake to a drained valley. From the beginning of the Cretaceous period the Great Valley has been the depository of the enormous masses removed by erosion from the rising land on the east, and to a less degree also of the débris from the Coast Ranges.

The entire depth of the strata resting in the Great Valley is not known. On the western valley border, in the vicinity of Mount Diablo, Turner[1] found an apparently conformable series ranging from the Knoxville formation (Lower Cretaceous) to the Pliocene, of a thickness which according to his sections probably aggregates 25,000 feet. It is hardly possible that the total thickness of Cretaceous, Tertiary, and Pleistocene deposits in the Great Valley reaches that enormous figure, but there is reason to believe that none of the wells put down in the valley have penetrated into Eocene strata, and the thickness of the older rocks is unknown.

Through the many deep borings made in the Great Valley in search of gas or artesian water, the knowledge of the deposits of the valley has been greatly increased. Few of these borings, however, afford any definite proof of the age of the strata passed through; the records, if procured at all, are often very carelessly noted, the determinations of the rocks encountered are commonly erroneous, and samples are rarely kept.

Dall and Harris[2] make the following pertinent statements in regard to the strata of the Great Valley on the authority of Jerome Hawes, of Stockton, who has for many years been engaged in boring artesian wells:

> In boring in the valley away from the foothills the strata exhibit great uniformity. They consist of clays and sands, the beds of clay becoming thicker as one bores deeper, sometimes reaching 100 feet without a break. Gravel is rare. * * * The sand and clay from the Sierra side is different in texture and color from that on the Coast Range or western side of the valley. But on the west, after boring through about 500 feet of Coast Range detritus, the drill comes to Sierra gravel and thereafter continues in it, showing that the latter underlies the Coast Range talus.

The wells at Stockton have reached a depth of 2,254 feet. At Sacramento[3] a well has been sunk to 965 feet through clay and sand and obtained some flowing water and gas. The strata are soft and the sands do not resemble the sandstone of the Ione formation. G. F. Becker, who examined some of the samples from this well, states that some of them were probably

[1] Turner, H. W., The geology of Mount Diablo: Bull. Geol. Soc. America, vol. 2, 1891, pp. 383-402. See also Anderson, F. M., A stratigraphic study in the Mount Diablo Range: Proc. California Acad. Sci., 3d ser., vol. 2, No. 2, pp. 155-248.

[2] Bull. U. S. Geol. Survey No. 84, 1892, pp. 195, 196.

[3] Bull. California State Min. Bur. No. 3, p. 11.

andesite tuffs. A well was recently bored on the Blair mining claim, about 2 miles south or southeast of Roseville, and coal seams, as well as "white volcanic ash," were reported to be found. The beds belong undoubtedly to the Ione formation (Miocene), but the report of the interstratified "volcanic ash" needs confirmation.

On the Haggin ranch on Arcade Creek, 5 miles east-northeast of Sacramento, a well was bored in 1872 in an unsuccessful search for artesian water. It attained a depth of 2,250 feet and encountered only soft formations. This is only 13 miles west of the first outcrops of the "Bedrock series" of the Sierra Nevada, and indicates a steeper slope of the pre-Cretaceous rock surface west of the valley border than east of it.

In 1891 a well was sunk in Wheatland, Yuba County, to a depth of 500 feet, mainly through greenish sand. At Sheridan, Placer County, a well was bored to a depth of 734 feet through clay and sand. Below 600 feet the drill passed through several hard strata of "cement" (tuff?) and a 1-foot layer of "crystallized quartz" (possibly a quartz bowlder). Two miles southwest of Sheridan, on the Lucas ranch, a depth of 600 feet was attained; below 100 feet of quicksand there was 500 feet of gray and blue clay, containing 4 feet of gravel in the middle.[1] Neither at Wheatland nor at Sheridan was artesian water obtained.

At Marysville wells have been bored to depths of more than 200 feet through clay and sand with a little gravel, without finding artesian water. A well bored in the tule lands south of the Marysville Buttes disclosed 400 feet of clay (with sand), in the middle of which was a thin stratum of gravel. No flowing water was obtained.

Under the term "alluvium" are classed the fluviatile deposits of clays, sands, and gravels formed by the present rivers during the progressive erosion of the older formations. The alluvium of the Great Valley has largely been formed by the erosion and redeposition of the older Quaternary strata covering the valley. The alluvial beds occupy a large space in the center of the valley, but there are good reasons to believe that their depth is relatively slight, probably at few places exceeding 100 feet; the lake of the Great Valley was drained only a relatively short time ago.

In the center of the valley Sacramento River pursues a winding course with numerous oxbow bends and cut-offs. The stream has built up embankments 1 to 15 feet higher than the land on either side; the slope from the banks toward the low lateral basins is in places as much as 12 feet in 1,000 feet. The main channel is of very irregular depth and width and has not sufficient capacity to carry off the winter floods; in consequence, during high water much of the flow escapes through sloughs and crevasses into the lateral basins on the east and west, converting them for the time into vast shallow lakes. The banks are from 1 to 2 miles wide and are formed in the main of comparatively solid sediments. Levees following the river protect these fertile bank lands at many places, but there is a noticeable lack of a systematic plan in the regulation of the river.

MINING DÉBRIS.

FEATHER RIVER.

The traveler approaching Feather River from the center of the valley begins to meet the effects of the débris from the hydraulic mines in the Sierra Nevada. The Sacramento carries practically none of this débris, but the Feather, the Yuba, the Bear, and the American are loaded with large quantities of gravel, sand, and silt. The general character of Feather River has changed considerably since 1850. The influence of the tide formerly reached up the Sacramento to the mouth of the Feather; now it is felt only to a point some distance below Sacramento. Prior to 1850, Feather River was a clear-water stream with well-defined banks, its bottom consisting of gravel and sand. At Yuba City the banks were 15 feet high and not subjected to overflow, except at certain places on the east side below the city.

At the present time the river between Rio Bonito, a few miles below Oroville and Marysville is pretty well defined between banks from 6 to 20 feet high, flanked, as a rule, by low bottom

[1] Eleventh Rept. State Mineralogist California, p. 319.

lands from 300 feet to half a mile wide; these are flooded nearly every winter. Below Marysville the channel has been filled in by the débris brought down from the Yuba and the Bear and the whole river bed has been raised until the stream has only a wide, uncertain channel in a sandy bed with almost even grade to the Sacramento; the bottom lands surrounding the river are more and more subject to overflow. Incidentally the overflows of the lowlands situated between the Yuba and Honcut, to the west of the railroad, have been greatly increased. The State engineer[1] remarks on this subject as follows:

It is known that in the past 40 years the bed of Feather River and that of the Sacramento below the junction with the former have been greatly raised, as indicated by the elevation of the low-water plane as follows: At Oroville, 5 to 6 feet; at Yuba City, about 13½ feet; at the mouth of the river, from 3 to 5 feet; at Sacramento, about 7 feet.

The average grade of the Sacramento from the mouth of Chico Creek to the mouth of American River gradually diminishes from 1.5 feet to 0.3 foot per mile. That of the Feather from Burts Ferry to the junction with the Sacramento gradually decreases from 1.5 feet to 1 foot per mile.

YUBA RIVER.

The greatest changes due to mining débris have been wrought in the lower course of Yuba River, from Smartsville to Marysville. An immense amount of fine débris has been spread out on the adjoining plains to a width of 1 to 3 miles, covering an area of 25 square miles with deposits of fine sand and gravel, rendering much valuable land unfit for cultivation, and necessitating the protection of the adjacent country by means of levees. The sandy plains are covered by a dense willow growth, and the stream meanders over them in changing channels. The grade of the Yuba in the lower stretches ranges from 15 to 5 feet per mile. Above Deguerre Point, nearer to the foothills, the grade reaches 20 feet per mile.

BEAR RIVER.

The conditions on Bear River between the foothills and its junction with the Feather near Nicolaus are similar to those on the Yuba, except that the area covered by mining débris is not quite so large. Between the Bear and the American a number of smaller watercourses, among which the principal are Coon Creek, Auburn Ravine, and Dry Creek, make their way across the plain in a westerly to southwesterly direction and finally lose themselves in the low basin east of the Sacramento.

AMERICAN RIVER.

American River, on emerging from the foothills, takes a southwesterly course, which it follows to a point near Sacramento, where it turns to a west-northwesterly direction; it joins the Sacramento a short distance north of the city. The river has a considerable grade and for the larger part of its course is well confined between its banks. Only near its mouth is there any danger of overflow, and that chiefly in the immediate vicinity of Sacramento. Sandy mining débris has filled the channel to a depth of about 10 feet near Sacramento, but the loss of valuable land by overflow is very much less than on the Yuba and the Bear.

SACRAMENTO VALLEY.

The monotonous surface of the alluvial plains of the Sacramento Valley is scarcely broken by any recognizable relief; the lowest depressions are covered with swamp grass and tule, among which are tortuous sloughs and sheets of standing water, widening in flood times to vast lakes. The only sharply salient features are the river banks of sand and clay, from a few feet to 20 feet high. The valley floor is the gently sloping surface of a Pleistocene lake bottom, only recently drained by constructive processes. The rivers are at their base-level and in their sluggish courses deposit the loads of sand and clay brought down from the mountains, corrade their banks, and endeavor to establish new and changing channels.

[1] Report to Legislature of California, 1880, pt. 2, p. 30.

TRIBUTARIES OF SAN JOAQUIN RIVER.

The general level of the San Joaquin Valley rises more rapidly toward the south than that of the Sacramento to the north, and this steeper grade finds expression in the lower reaches of the tributaries to San Joaquin River. In order from north to south these tributaries are the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced. The following description is quoted from a report by Lieut. A. H. Payson:[1]

On each there is one point where the canyon proper abruptly ends and the valley begins. Below the canyon, while the undulations of the foothills continue, the upland banks, though sometimes approaching each other in points, are generally separated by a wide stretch of fertile bottom, until finally this distinction disappears and both become merged in the general level of the plain. The slopes will meantime vary from 2 or 3 feet per mile in the plain to 8 and 10 feet at the entrance to the canyon, thence increasing rapidly in the first few miles to 20 or 30 or even 40 feet.

As we go south and the average height of the main San Joaquin Valley increases we find that its tributaries have worn for themselves deeper notches in the country; the banks are higher and narrower, while above them will be a second and sometimes even a third terrace of older origin and coarser material.

Crossing the plain parallel to the San Joaquin and 10 or 15 miles east of it, the courses of the Cosumnes, Mokelumne, Dry Creek, and Calaveras are marked by a line of growth in the otherwise treeless distance, while on approaching the Stanislaus, Tuolumne, or Merced nothing is seen of the river until just at its edge, whence its valley is looked down into from bluffs 80 to 150 feet in height, and on the two last named this peculiarity is preserved nearly throughout their length.

The three southern streams fall directly into the San Joaquin in its upper course, to the detriment of the most critical part of its navigation, while the others have their outlet through a network of tidal arms in low tule lands, and are thus given a place of harmless deposit for much of their sedimentary load when spread out in times of flood.

Before the destructive effects of gravel mining had made themselves felt in these valleys, the streams, perfectly clear in low stages, were between high and solid banks grown with large timber, and though these were overflowed in exceptional seasons, the floods staid but a short time on the land and were of benefit rather than harm. The soil was a black loam and very rich. The first and greatest of the changes came during the extraordinary flood of 1861–62. In that winter immense masses of detritus, the result of 10 years and more of mining, were swept down along the rivers, their beds were choked and raised, their banks torn out to excessive widths, and large areas of good land ruined from being thickly overlaid by sand and gravel.

But all the rivers have not been equally affected. The Cosumnes is now by far the worst of the southern streams, though even on it the destruction does not approach in magnitude that on the Yuba and the Bear. Its bed at the mouth of the canyon has been substantially obliterated, the deposits being nearly level with the banks, and below for several miles has been torn out to five and six times its normal width and choked with sand and gravel. The filling of its bed is estimated at 6 feet 8 miles above the Southern Pacific Railway crossing, 15 feet at a point 17 miles above, and 20 feet at the entrance to the canyon.

Next to the Cosumnes in order of damage comes the Calaveras, and although here the ill effects are not so marked just now, it is the most threatened from the present choked condition of its own and tributary canyons.

The most important of the rivers considered is the Tuolumne, formerly itself navigable for some 15 miles above the mouth. It empties into the San Joaquin below and near the head of its navigation, upon which it immediately produces a marked and prejudicial effect. Though badly filled, probably 15 feet, at its exit from the canyon, and much spread out for 10 or 12 miles below, its bed soon gets between high and well-defined banks.

The Stanislaus, though the deep places in its bed have been filled up to a uniform grade and its channel way considerably widened for some 10 miles, has not been appreciably raised in low-water level at Knights Ferry, in the foot of the canyon; its water is quite clear in low stages, and its banks seldom overflowed in floods, and then only for very short periods.

The same description will apply to the Mokelumne, but its bed has probably been raised 5 or 6 feet at Lancha Plana, and its floods are more frequent and spread over wider and more valuable tracts of bottom land.

QUANTITY OF MINING DÉBRIS.

By G. K. Gilbert.[2]

The belt of hydraulic mining in the Sierra Nevada traverses the drainage basins of a series of streams tributary to the Sacramento and the San Joaquin. On the tributaries of the San Joaquin the quantities were relatively small—so small as to produce little or no effect on the navigability of the rivers. On Feather River proper the mining operations were more extensive,

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[1] Payson, A. H., Mendell, G. H., Report upon a project to protect the navigable waters of California from the effects of hydraulic mining: House Ex. Doc. 98, 47th Cong., 1st sess., 1882, pp. 47–48.

[2] During the last few years Mr. G. K. Gilbert has undertaken, under the direction of the United States Geological Survey, a long series of experiments on the transportation of débris by running waters. It is hoped that these examinations will throw more light on the movement of débris in the rivers and make it possible to control the débris more effectively. Mr. Gilbert has, in connection with this work, made some detailed surveys of the old hydraulic excavations and has generously permitted the publication of the results in this report.

but still small as compared to those on the Yuba, the Bear, and the American. Of the quantity of material excavated in the basins of those three rivers a number of estimates have been made, the estimated amount varying through a wide range. The latest of these estimates which make use of first-hand data is given in the report of a board of Army engineers headed by Lieut. Col. W. H. H. Benyaurd, which is contained in the annual report of the Chief of Engineers, United States Army, for the fiscal year ending June 30, 1891. It is made by F. C. Turner, assistant engineer, and applies to the year 1890. For the present purpose this estimate is the most available, especially as it was made some years after the stoppage of general hydraulic mining, whereas a number of the earlier estimates were made during the progress of the mining. It constitutes part of the report of a detailed reconnaissance of the region of hydraulic mining, in which a large body of valuable data were accumulated. The method of making the estimate is not stated by Mr. Turner, but may be assumed to have been indicated in general terms in the following passage from the report of the board:

The usual manner of estimating the amount of material moved is to determine the amount of water used in miner's inches and assign a duty to the inch. This, however, varies in different localities, in some places being as low as 2,000 and in others as high as 2,600 cubic feet in 24 hours. In the usual determination the quantity is taken at 2,230 cubic feet in that time. The duty depends upon the quantity of water used, the pressure, the character of the material washed, and the grade and size of the sluices; character of material and grade are the ruling elements. With heavy material the duty may be as low as 1.5 to 2 cubic yards and with light material as high as 10 cubic yards per inch. Instances are quoted in the report of the State mineralogist for 1889 where, with increased grade of sluices (12 and 18 inch grades), the duty attained was 24 and 36 yards, respectively. The usual calculations are upon a basis of 3½ cubic yards. It will therefore be seen that great variations must exist in the estimates of amount of material that has already been mined out.

Impressed by the uncertainty of this mode of estimation, in which no engineer appears to have reposed great confidence, I undertook to check it by an independent estimate based on an entirely different procedure, namely, the measurement of the cubic contents of the cavities produced by the excavation. This work was carried on in the spring and autumn of 1908, and after a few preliminary experiments the following method was adopted and followed:

The surveying instruments were a plane table and a stadia rod. With these a traverse was run through the bottom of each cavity or along its edge, and where the area was large a traverse circuit was completed. From the stations of the traverse numerous points were determined by stadia and others by angulation, the position and altitude of each being fixed. A complete sketch was made of the rim or outer margin of the excavation, and for a short distance outside the rim the ground was contoured. The scale adopted was 200 feet to 1 inch and the contour interval was 20 feet. After the completion of the field work the contours of the ground previous to the excavation were restored by estimate, use being made of the determined contours outside the rim and of the determined courses of drainage lines outside the rim. With the aid of these restored contours and the determined points within the area of excavation, a series of cross sections were constructed, and from these the volume of the excavation was computed.

The precision of this method can not be definitely stated, as there were no absolute checks on the accuracy of the restored contours and the data controlling the restoration varied in cogency through a considerable range. In the opinion of the writer, who was also the surveyor, the general accuracy is such that the grand totals are true within 10 per cent, although many individual measurements have a lower precision. [The appearance of some of the hydraulic mines, the tailings accumulated, and the method of mining are shown in Plates II and III.—W. L.]

The work was not carried on through the entire hydraulic district, but comparison with the Turner estimate indicates that it covered about four-fifths of the excavation in the basin of Yuba River and three-sevenths of the total excavation of Yuba, Bear, and American rivers. The following table gives the results in some detail and also compares them, so far as practicable, with the items of the Turner estimate. The difference in method of estimate led to a difference in the classification of the excavations, so that the comparison can not be refined, but it serves, nevertheless, as an effective check on the Turner estimate.

Volume of hydraulic excavation in part of the Yuba basin, as estimated by G. K. Gilbert in 1908 and by F. C. Turner in 1889–90.

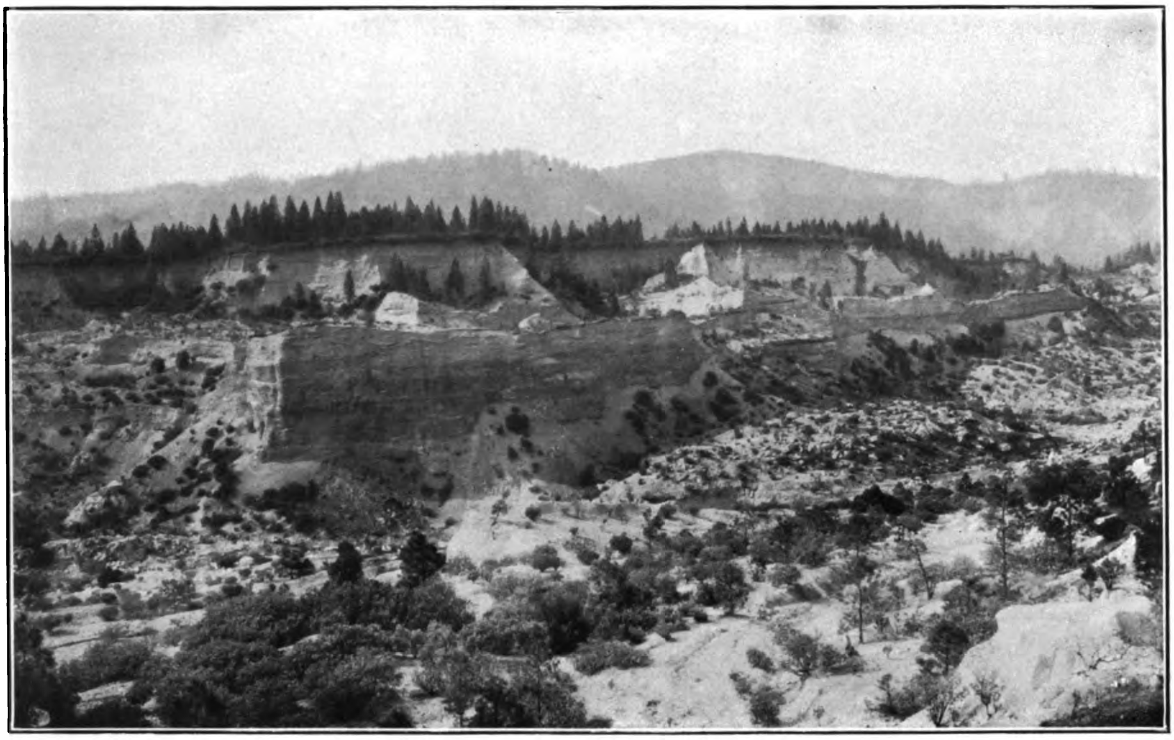
District, mine, or locality.		Volume, in thousands of cubic yards.	
1908	1889–90	1908	1889–90
Camptonville (7,100), Youngs Hill (7,500), Galena Hill (4,400), Weeds Point (3,000).	Willow Creek (5,800+), Camptonville and vicinity (1,500).	22,000	7,300
Indian Hill	Indian Hill	7,800	4,500
Moores Flat (21,000), Orleans Flat (3,400), Snow Point (3,900)	Moores Flat, Orleans Flat, and Snow Point	28,300	26,000
Woolsey Flat	Woolsey Flat	20,700	4,100
Badger Hill and English Co.	Badger Hill and Cherokee (10,000), English Co. (7,000)	22,600	17,000
North Bloomfield (main pit, 64,400; minor pits, 13,600)	North Bloomfield (29,000), Last Chance, Porter, etc. (3,000).	78,000	32,000
North Columbia (main pit, 89,500; Howleys, Ohio, Neversweat, etc., 2,560).	Columbia Hill (20,000+20,000)	92,060	40,000
Union Gravel	Union Gravel	9,100	10,000
Yuba (Grizzly)	Grizzly Hill	1,400	1,000
Paterson and vicinity	Paterson claims (5,000), Montezuma Hill (500)	7,800	5,500
North San Juan (25,350), Manzanita and American (47,900), Bed Rock (10,050), Buckeye (12,650).	North San Juan and part American (20,000+500), Sweetland Creek, Birchville, Manzanita, and part American (60,000).	95,950	80,500
Esperance (and Kinney)	Esperance	3,500	1,500
French Corral	French Corral	16,050	31,000
Omega	Omega	22,700	12,000
Alpha and vicinity	Alpha (5,000), Place, Merrill, etc	9,000	7,000
Sailor Flat and Blue Tent	Sailor Flat and Blue Tent	46,200	15,000
Cement Hill (?)	Nevada City, Cement Hill	1,800	2,550
Rough and Ready, Randolph Hill and vicinity	Rough and Ready, Randolph Hill	910	3,000
Nevada City (Manzanita or Sugar Loaf) (6,000), Hirschman, etc. (6,400).	Nevada City, Sugar Loaf	12,400	10,000
Murchies, McCutcheon, Charonnat, etc	Murchies, Gold Flat, etc	2,100	500
Scotts Flat	Scotts Flat	18,600	12,000
Smartsville and Timbuctoo (24,460), Mooney Flat (3,800)	Smartsville, Timbuctoo, and Mooney Flat	28,260	44,800
Sicard Flat	Sicard Flat	3,030	1,700
Depot Hill	No record	3,900	....
Railroad Hill	do	2,700	....
2 miles west of Parks Bar Bridge	do	320	....
Dry Creek	do	40	....
2 miles west of Grass Valley	do	30	....
Total		557,250	368,950
Percentage		1.51	1.00

Examination of the table shows that a few of the earlier estimates are higher than the later, but the majority fall below, and the new general totals exceed the earlier by 51 per cent. The difference is in part explained by the fact that some mining took place in the interval between 1890 and 1908. A number of mines were worked for short periods or in a small way under permits from the débris commission, and there was some surreptitious work without permits. During the surveys in 1908 it was easy to see that certain parts of the excavations, on which a young forest growth had sprung up, were of early date, and that other parts, still bare of vegetation, were relatively recent, but it was not practicable either to infer dates with approximate accuracy or to estimate separately the more recent work. It is believed, however, that the work subsequent to 1890 can account for only a small portion of the discrepancy between the two estimates and that the greater part of the 51 per cent of difference inheres in the methods of estimation and the data employed. Assuming the substantial accuracy of the later estimate, and assuming further that the ratio of difference derived from the totals of the table may be applied as a correction to the other portions of the Turner estimate, I have deduced revised estimates for the total hydraulic excavation in the combined Yuba, Bear, and American basins. Turner's summary is as follows:

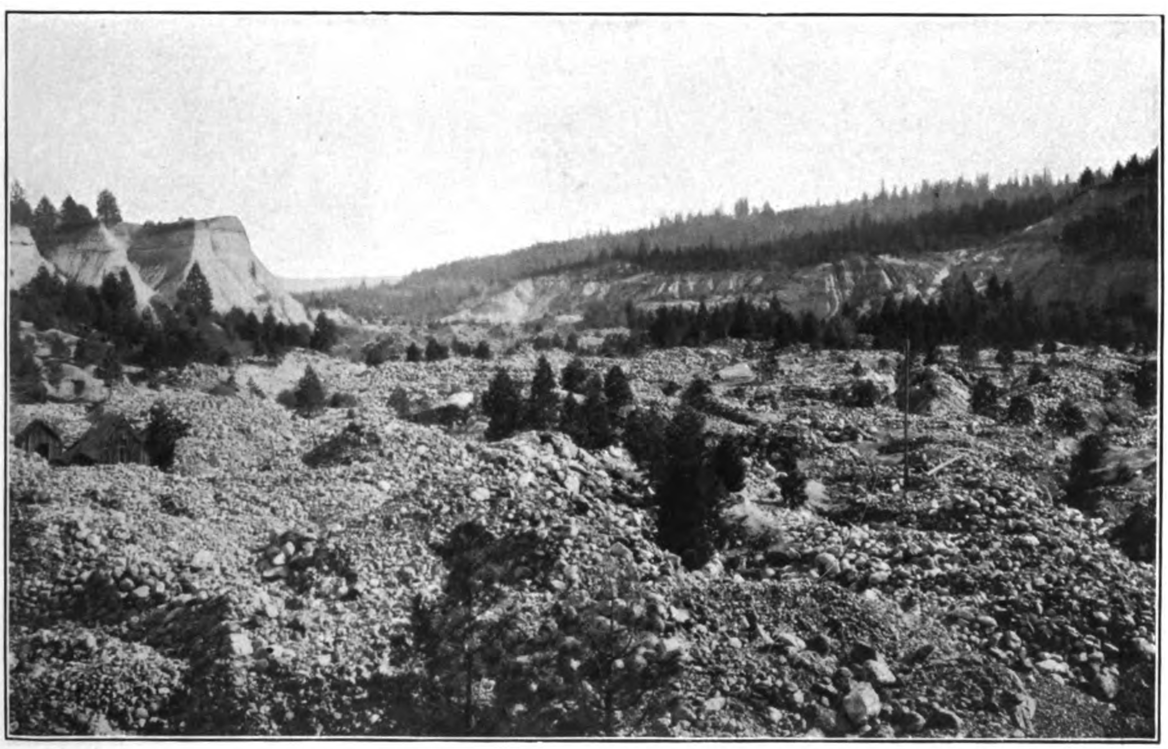
Material excavated by hydraulic mining in the basins of Yuba, Bear, and American rivers.

	Cubic yards.
Yuba River	452,690,000
Bear River	234,650,000
American River	170,330,000
	857,670,000

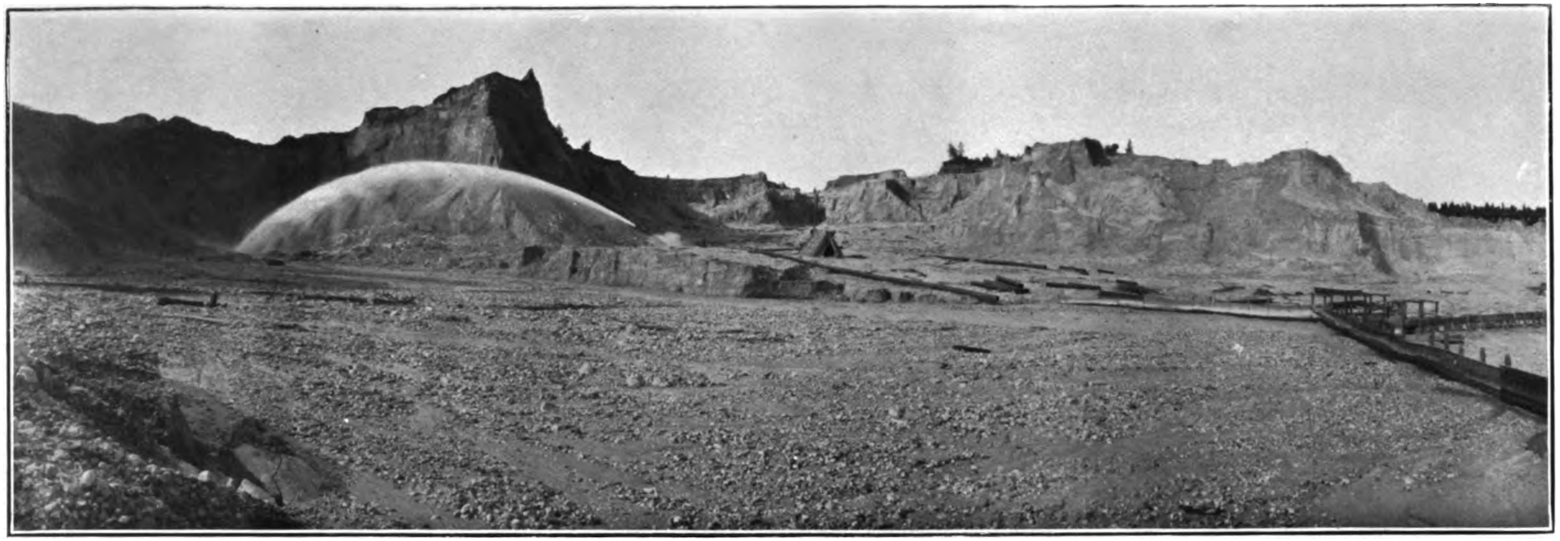
The application of the ratio 1.51 to these quantities yields for the Yuba Basin 684,000,000 cubic yards, for the Bear 354,000,000 yards, and for the American 257,000,000 yards. The values thus derived have been adopted for the Yuba and American basins but have not proved



A. MANZANITA HYDRAULIC MINE, NEAR SWEETLAND, NEVADA COUNTY.
Bedrock is granodiorite. Photograph by G. K. Gilbert. See page 123.



B. MOORES FLAT HYDRAULIC MINE, NEVADA COUNTY.
Photograph by G. K. Gilbert. See page 141.



A. HYDRAULIC OPERATIONS AT NORTH COLUMBIA, NEVADA COUNTY.

Photograph by J. C. Hawver. See page 139.

B. HYDRAULIC DIGGINGS AT NORTH COLUMBIA, NEVADA COUNTY.

Showing banks of accumulated tailings. Photograph by J. C. Hawver. See page 139.

satisfactory for the basin of the Bear. The quantity of mining débris accumulated in the canyons of the Bear and its tributaries has twice been estimated with more care than was bestowed on similar deposits along the other rivers, and something is known also of the volume of the river's piedmont deposit. When these estimates are considered in connection with the small discharge of the Bear and other factors affecting the ratio of the local arrest of débris to the total output of the mines, good reason is found to regard the estimate of 354,000,000 yards as excessive. As all the quantities involved in the discrepancy were subject to considerable uncertainty the adjustment was of the nature of a compromise and the share assigned to the output of débris was 100,000,000 yards, reducing the estimate to 254,000,000 yards.

The only other stream to receive mining débris and convey it eventually to the Sacramento is the main branch of the Feather. Turner's estimates do not include the mines of its basin, and my own observations covered but a small area. In the report of the State engineer of California, Wm. Ham. Hall, for 1880, pages 23–24, estimates are made for the "water used and material washed out per annum" for the several river basins of the Sierra from the American northward. For the basin of the Feather the estimate of material washed is 12,687,500 cubic yards, and the sum of the estimates for the Yuba, Bear, and American is 36,480,500 cubic yards. Lieut. Col. Mendell makes a similar estimate for the year 1880,[1] in which the corresponding figures are 4,407,770 and 31,070,094. Mendell also gives with full detail the assessors' returns of the water used in mining. Hall and Mendell both qualify their estimates—Hall because his data were incomplete and Mendell because the method used was unsatisfactory. In 1881 the canyons and mining regions of the Feather and Yuba were inspected by Marsden Manson, and his report[2] tends to discredit the estimates based on assessors' returns. He found that much of the water ascribed to hydraulic mining was actually used in drifting and quartz mining and in other ways not involving the handling of large quantities of earth.

Disregarding for the moment Manson's implied criticism, accepting the estimates of Hall and Mendell, and assuming further that the total output of débris for the several basins for the whole period of hydraulic mining was proportional to the annual output, I have made two computations of the total output of the Feather. The figures quoted from Hall's table give 366,200,000 yards and the figures from Mendell's table 186,600,000 yards. Various details reported by Manson and Turner, as well as data from other sources, indicate the probability that both these figures are excessive. On the other hand, a minimum estimate is suggested by the volume of the piedmont deposit of the Feather, which occupies the river bed between Oroville and Marysville. Hall estimated this, from surveys probably made in 1879, at 18,257,000 yards,[3] and the observations of Turner indicate that only moderate additions were made in the following decade. The suggested minimum is 40,000,000 yards, and this might serve as a practical estimate, so far as conditions of the lower river are concerned; but it would probably not be coordinate with the estimates for the other basins, which aim to show the full extent of the exploitation of the auriferous deposits. According to Manson the tailings from the greatest operations were chiefly lodged in a permanent way in the American Valley, an opening in the heart of the mountains. Between the limits 40,000,000 and 186,000,000 the value of 100,000,000 yards is arbitrarily chosen. Adding the estimate for the Feather Basin to that for the three basins farther south gives a total of 1,295,000,000 cubic yards as the output of the hydraulic mines on streams whose waters join the Sacramento.

TERRANES OF THE EASTERN BORDER OF THE VALLEY.

GENERAL FEATURES.

Between the alluvium of the central valley and the first bedrock hills of the Sierra Nevada there lies, with flat westward dip, a series of formations ranging in age from the late Cretaceous deposits to those of the present time. Their occurrence and interrelations enable the observer to deduce with considerable certainty the geologic history of the western foot of the range.

[1] Rept. Chief Eng. U. S. Army, 1881, pp. 2486–2487, 2494–2501. [2] Rept. Chief Eng. U. S. Army, 1882, pp. 2604–2612.
[3] Rept. State Engineer, 1880, p. 11.

One of the first generalizations to be drawn from their study is that the intense diastrophism of the Coast Range in Cretaceous and post-Cretaceous time was represented at the edge of the massive crust block of the Sierra only by faint pulsations; almost their only expression is found in the evidence of a long series of advances and retreats of the shore line, some more prominent, others very slight, all recorded faithfully by the overlapping formations.

Gently, as a rule almost imperceptibly, the older formations emerge from the overlapping alluvium. The ground rises in gentle swells to softly undulating hills with fine gravelly soil; the little watercourses are definitely marked with steeper grades and deeper trenches. The erosive power is still slight, but the tendency to lateral corrosion and consequent enlargement of the flood plain is very pronounced. The older Quaternary deposits of gravel, clay, and sand are being more or less slowly dissected during the process of degradation to a base-level about 350 feet below the old one. At some places a regular and slight slope of Pleistocene gravels reaches up to the foothills. Elsewhere long embayments of alluvium may extend up toward the first outcrops of the bedrock series and from these depressions the earlier deposits are attacked with more vigor, producing a complex of flat-topped hills.

CHICO FORMATION.

The Shasta series, or Lower Cretaceous, is entirely lacking along the valley border. The Chico formation (Upper Cretaceous) is represented abundantly in Butte County, in the northern part of the Sacramento Valley, but is almost wholly lacking along the valley south of parallel. 39° 30′. The elevation at which the formation occurs gradually diminishes toward the south. The Chico wherever found rests directly and unconformably on the pre-Cretaceous bedrock This indicates either that a period of erosion intervened between the Shasta and the Chico, or perhaps rather that the shore line during the Shasta epoch was located considerably west of the line of the foothills. The geologic history of the valley border may thus be assumed to begin with the Chico transgression.

The Chico formation occurs at two localities in the vicinity of Folsom, in the latitude of Sacramento; both are noted by Whitney,[1] who also mentions several other localities, but during the geologic mapping of the Sacramento quadrangle only these two could be established beyond doubt. Fossils characteristic of the Chico have been collected in both localities.[2] At one—Rock Corral, 3 miles north-northwest of Folsom—the strata rest upon the granitic rocks, emerging at that point from the covering formation of the Great Valley. At this place a well was sunk about 30 years ago to a depth of 120 feet. The fossils were found at a depth of 43 feet in sandstone and constitute a typical Chico fauna. The exposures are poor, but in a small trench in the decomposed surface material at this place the writer succeeded in finding imperfect casts of shells that are probably referable to the Chico. The exact extent of the Chico on the surface is a matter of much doubt. For a mile south of the Rock Corral locality there is between the Pleistocene and the granite an area covered by white clay or sandy clay. This material immediately underlies the andesites and gravels between Rock Corral and Folsom and is shown also under the andesite opposite Folsom and under the Orange Vale bluff; in this terrane no fossils have been found, and from its position and general character it is believed to belong to the Ione formation (Miocene).

At Folsom, where American River, emerging from the foothills, has cut down about 100 feet through Pleistocene and Neocene deposits and deposited large amounts of late Pleistocene gravels, another body of Chico rocks is exposed. It is on the north bank of the river one-fourth mile below the suspension bridge and is or was covered by heavy Pleistocene gravel, now largely removed by mining processes. The Chico beds lie in the middle of the old diggings on the first outcrops of bedrock visible along the river, only a few feet above the water. About 10 or 12 feet of soft white clay and greenish clayey sandstone, with abundant coaly particles and indistinct vegetable remains, are shown in the exposures, the beds dipping gently westward.

[1] Whitney, J. D., Geological Survey of California, Geology, vol. 1.

[2] For lists of fossils see Turner, H. W., The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 458-461.

On the bedrock is a little fine greenish, well-cemented metamorphic and quartz gravel, which at the time of visit was being mined from small shafts and washed for gold.

Slight as these exposures are, there is still in their position some indication of the character of the surface over which the Chico transgression extended. At Rock Corral, where the Cretaceous attains an elevation of 300 feet, the granite rises 150 feet in a distance of 2,000 feet toward the north. At Folsom the small remnant of the Chico lies in a distinct old depression 150 feet above the sea, the rim to the northeast rising several hundred feet in less than a mile. The auriferous gravel underlying the beds points to a watercourse antedating the Chico. It appears permissible to draw the conclusion that the Chico was laid down on an uneven surface with a relief at least as prominent as the first emerging foothills show to-day. The Chico transgression moved the shore line eastward at least as far as the 300-foot contour.

The next exposure of the Chico is at Pentz, in Butte County, north of Table Mountain.[1] A few miles farther north this formation is well exposed in the deeper creek trenches, particularly near Mineral Slide, on Little Butte Creek; at Centerville, on Big Butte Creek; and in the canyon of Chico Creek above the town of Chico (Pl. XVI, *B*, p. 88). The sandstones of the Chico formation rest with very gentle westerly dip on the eroded surface of the "Bedrock series," here consisting of slates or greenstones, and are covered with slight unconformity by shore or flood-plain gravel which in turn underlies heavy beds of andesitic tuffs. The contact of the Chico and the "Bedrock series" lies here at an elevation of 1,000 to 1,500 feet. Somewhat farther north, along Deer Creek, just over the line in Tehama County, another exposure of Chico is found at an elevation of 2,000 feet.[2] Thirty miles farther north, in the southern part of Shasta County, the exposures of Chico rocks, surrounded by Tertiary beds, attain an elevation of 3,000 feet. So far as can be told from the scattered exposures, the Chico rises gradually from an elevation of 300 feet in Sacramento County to one of 3,000 feet in southern Shasta County, but it is not safe to say that this is due entirely to differential elevation for an epoch of erosion intervened between the Chico and the Miocene, and it is quite possible that much of the Cretaceous toward the south has been carried away.

TEJON FORMATION.

In the Marysville Buttes, in the center of the Sacramento Valley, several hundred feet of marine Eocene beds (Tejon formation) are exposed,[3] uplifted by volcanic agencies and consisting of greenish sands and shales containing an abundance of characteristic fossils, such as *Trochosmilia striata* and *Cardita planicosta*.

Along the base of the Sierra Nevada the Tejon has been found at only one point, on Merced River 1 mile south of Merced Falls, in Mariposa and Merced counties.[4] Here several small flat-topped buttes of sandstone with characteristic marine fossils rest directly and almost horizontally on the nearly vertical Mariposa slates at elevations of 500 to 600 feet, the top of the sandstones reaching to 800 feet. At this place Merced River emerges from its canyon, which is here only from 200 to 300 feet deep. Immediately east of this point the first greenstone ridges of the Sierra rise to elevations of 1,000 feet. To the west the Miocene (Ione formation) overlies the Tejon formation with unconformity.

All this shows plainly that the relief of the foothills in Eocene time differed little from that of the later part of the Tertiary period. As no rocks belonging to the Tejon formation underlie the Ione in similar situations north of Merced River, it is probable that an epoch of erosion intervened between the Eocene and the Miocene, and that during that interval the shore line retreated a considerable distance westward. Certain of the lower auriferous gravels in the old river bed near the valley border are probably of Eocene age; the stream gravels on the bedrock at the lowest points in the Miocene courses of American and Yuba rivers are considerably lower than the top of the Ione formation.

[1] Turner, H. W., The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 458–461.
[2] Diller, J. S., Lassen Peak folio (No. 15), Geol. Atlas U. S., U. S. Geol. Survey, 1895.
[3] Lindgren, Waldemar, Marysville folio (No. 17), Geol. Atlas U. S., U. S. Geol. Survey, 1895.
[4] Turner, H. W., and Ransome, F. L., Sonora folio (No. 41), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

IONE FORMATION.

DEFINITION.

During the Miocene period and contemporaneously with the accumulation of the later prevolcanic gravels on the slopes of the Sierra Nevada there was deposited in the gulf then occupying the Great Valley a sedimentary series of clays and sands to which the name Ione formation has been given. The water in this gulf was probably brackish; no marine fossils have been found in the Ione formation along the foot of the range, but fossil leaves, vegetable material, and, in places, coal are abundant. At the mouth of the rivers which descended from the Tertiary Sierra Nevada extensive delta deposits were accumulated, and it is thus difficult in many places to draw any exact line between the Ione formation and the river gravels proper. The gravels in the formation are locally auriferous, though generally poor, because spread over large areas.

The lowest and oldest Tertiary auriferous gravels lie in troughs over which the Ione formation has transgressed, in places at depths of more than 500 feet. At many localities the sandstones and clays of the formation merge directly into the upper river gravels of the so-called benches. On the other hand, the thick gravels of the rhyolitic period are distinctly later than the Ione formation. Turner has shown that in the Jackson quadrangle extensive shore or delta gravels of interrhyolitic age rest on the eroded surface of the Ione. (See Pl. XI, *B*, p. 72). The Ione formation belongs to the late Tertiary and is believed to be of Miocene age.

The greatest thickness of the formation measured is in Calaveras County in the Jackson quadrangle, where Turner has determined it to be about 1,000 feet. Post-Ione erosion has removed the formation entirely over large areas.

DISTRIBUTION.

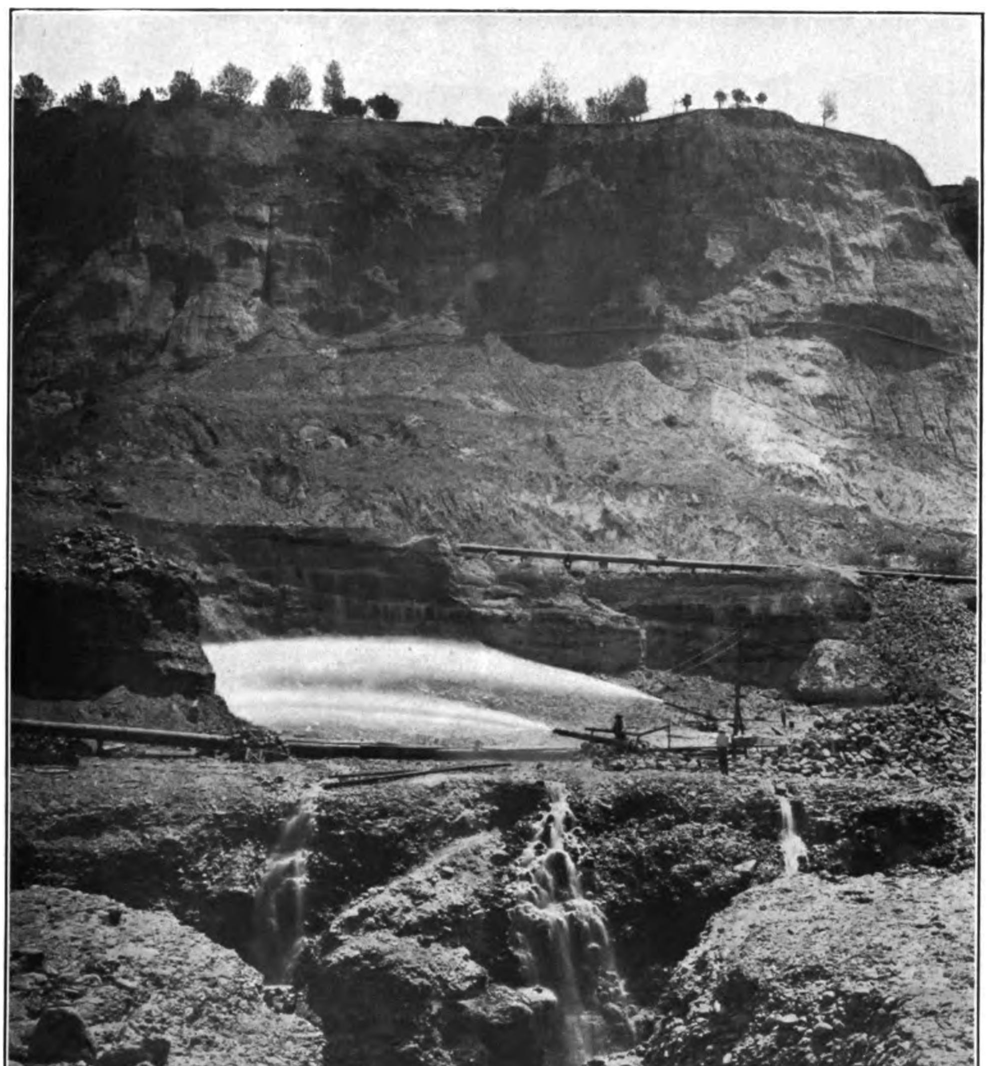
The most northerly exposures of the Ione, north of the Sierra Nevada, have been observed by Diller on Little Cow Creek and Pit River in the northwest corner of the Lassen Peak quadrangle, Shasta County. The clays and sands are here directly overlain by andesitic tuffs and rest on metamorphosed slates of Jurassic or Triassic age at an elevation of about 2,000 feet. South of this locality few exposures are seen until the Oroville Table Mountain is reached, a distance of nearly 100 miles. At this place a capping of basalt, somewhat earlier than the andesitic flows, has preserved the Ione intact. The formation here consists of fine gravels, white clays, and sands, and reaches to elevations of about 1,200 feet. (See Pl. IV, *B;* fig. 4, p. 86; and fig. 5, p. 90.) With insignificant exceptions, no further exposures occur between this point and Lincoln, in Placer County, where some white clays are preserved underneath a capping of andesitic tuff in the midst of Quaternary gravels and a few miles west of the first outcrops of the pre-Cretaceous rocks, usually referred to by the collective name "Bedrock series."

About 40 miles northwest of Lincoln, in the late Tertiary andesitic volcano of Marysville Buttes, clays, sands, and gravels of Miocene age have been brought up by the intrusion of igneous bodies and, although they are so much disturbed that the stratigraphic sequence can not be made out, there is strong probability that these strata should be identified with the Ione. They contain marine fossils associated with impressions of deciduous leaves, and the gravels contain some gold.

South of Lincoln the Ione formation is better exposed because it has been protected by andesitic tuff, but it does not reach a higher elevation than about 200 feet. South of American River the outcrops are more extensive, and the formation attains its greatest development in the foothills of Calaveras County. The lower part, consisting of white clay and sand, reaches a thickness of 860 feet or more and contains beds of lignite of poor quality. Above this rests a white sandstone which attains a thickness of 100 feet or more. A clay bed, also of light color, 100 feet thick, overlies this sandstone. Near Valley Springs the Ione attains elevations of 1,000 feet, and its highest members are probably several hundred feet above the deepest gravels of the Tertiary Calaveras River, which here debouches into the plains but which is not visible in this vicinity.

A. LOWEST BED OF COARSE AND BOWLDERY GOLD-BEARING GRAVEL AT CHEROKEE MINE, BUTTE COUNTY.

Photograph By Waldemar Lindgren. See page 86.



B. HYDRAULIC MINE AT CHEROKEE, BUTTE COUNTY.

Photograph by J. S. Diller. See page 86.

In front of the Gopher Ridge, a mass of greenstone rising abruptly in front of the bare foothills, the formation lies at elevations of 500 feet. About 25 miles to the south the formation lies in a similar position and rests against greenstone or Jurassic slate at the same elevation. Just south of Merced Falls, in the southwestern part of the Sonora quadrangle, the Ione formation overlies with slight unconformity the marine Eocene sandstones, of which but few exposures are preserved.

From all this it appears that during the later part of the prevolcanic gravel period the Ione formation transgressed along the whole front of the Sierra to a present elevation of somewhat more than 1,000 feet. So far as can be judged from the present exposures there has been little differential elevation along the front of the range since the time of the deposition of the formation. In other words, the fluctuations of the shore line are now indicated by horizontal lines at least between the Oroville Table Mountain and the foothills of Calaveras County.

POST-IONE EROSION.

The extent of the erosion which followed immediately after the deposition of the Ione formation along the foothills was greater than would be supposed from a study of the deposits in the rivers higher up in the range. The sequence is particularly well shown around the Oroville Table Mountain and in the foothills of Calaveras County. At the former place the andesitic tuffs (Tuscan tuff of Diller), which in Placer County appear to overlie the Ione formation conformably, are at least 500 feet below its top members. At the mouth of the old Yuba River there is a conspicuous absence of the Ione formation and the andesitic tuffs rest immediately on the bedrock, at elevations as low as 200 feet, and in the old river channel lie immediately above the heavy gravels, which are presumably of Eocene age. At this locality no extensive mud flows of rhyolitic character appear to have reached the valley, although they are abundantly present in the longitudinal basin which begins at North Columbia, Nevada County, 15 miles east. At the mouth of the Tertiary Calaveras River, on the other hand, shore gravels or delta gravels spread out up to a present level of 500 feet, and these gravels rest on the gently eroded surface of the Ione formation.

These interrhyolitic gravels were again subjected to some erosion; immediately after this followed the prolonged epoch of andesitic flows. The tuffs which were spread over a large part of the Sierra Nevada were worked over by the rivers and spread as thick masses of volcanic gravels and sands over the eroded surface of the Ione formation and the interrhyolitic gravels.

VOLCANIC FORMATIONS ALONG THE VALLEY BORDER.

The Tertiary volcanic rocks along the valley border comprise rhyolite, andesite, latite, and basalt. Few of these flows originated at the place where they are now found. Most of them were derived from volcanic vents in the higher part of the Sierra and flowed down the slope, some of them for distances of 60 miles or more.

RHYOLITE.

During the time of the rhyolitic flows in the upper range some material of this kind undoubtedly found its way to the valley along the old river courses, but it is not in a form distinctly recognizable as rhyolite tuff. At one place only the rhyolite reached the valley border—in the vicinity of Valley Springs, in Calaveras County, close to the mouth of the ancient Calaveras River. A few small areas of rhyolitic tuff here overlie the Ione formation at elevations of about 500 feet, and are in turn covered by andesitic tuffs and Quaternary gravels.

ANDESITE.

The andesitic flows that reached the valley are throughout of fragmental character and consist of a hard, tough, cemented breccia of brown or purplish color, which contains a large number of pieces of massive andesite. This tough breccia undoubtedly came down from volcanoes located high in the range and is not the result of ash showers or fluviatile concentration.

Associated with these beds are, however, andesitic conglomerates, fine-grained tuffs, and volcanic sandstones, which, of course, have been transported from the débris of andesitic areas higher up in the range.

North of Table Mountain, in Butte County, large areas of andesitic tuffs reach down to the valley border and, in fact, cover completely the older underlying rocks.

South of Table Mountain, in Yuba and Nevada counties, no andesite flows reach the valley; they were apparently prevented by the high greenstone ridges which here formed a barrier toward the east. The only exception is at Smartsville, where the Tertiary Yuba River broke through these barriers. Here a thin flow of cemented tough breccia and andesitic conglomerate, not more than 150 feet thick, covers the prevolcanic gravel. Below Smartsville the andesitic masses spread out over a large area skirting the foothills for some distance to the south at an elevation of about 200 feet; they are here not over 50 feet thick, and consist of dark-colored volcanic conglomerate capped by a thin layer of andesitic breccia. About 25 miles south of this place, between Lincoln and Folsom, in Placer and Sacramento counties, andesitic rocks appear along the valley border for a distance of 15 miles; they overlie auriferous gravels or the Ione formation and are nowhere over 100 feet in thickness; Pleistocene gravels cover the andesite on the west. Exposures at Folsom, for instance, show above the Ione formation 15 feet of andesitic gravel, 20 feet of fine-grained andesitic tuff, and a capping of 40 feet of hard, tough breccia. For 30 miles southeast of Folsom, or to Ione, a little town in Amador County, no volcanic rocks appear, but from Ione southward as far as Merced River, near the southern boundary of the area described in this report, andesitic detrital rocks form a belt which follows the foothill region west of the last outcrops of the "Bedrock series." These andesitic tuffs and gravels overlie the Ione formation but are within a short distance covered by the Pleistocene gravels of the rolling foothills of the valley. The beds grade in places into material which contains few recognizable volcanic fragments. They are well developed, for instance, at Knights Ferry, on Stanislaus River, where they form flat-topped hills about 200 feet high immediately in front of the first greenstone ridges of the Sierra Nevada.

BASALT AND LATITE.

Basaltic rocks reach the valley border at two places only. At the Oroville Table Mountain a basalt flow 300 feet in thickness covers the Ione formation, and small buttes of the same rock extend for several miles into the valley. It is probable that the basalt was erupted at some point not far distant from the present flow. There is, indeed, at Cherokee some evidence tending to show that part of it at least was erupted in that immediate vicinity.

On the other hand, the basaltic rock of the Tuolumne Table Mountain, near the south end of the area discussed, reached the valley as the final part of a narrow flow which originated far up in the range, in the vicinity of the Dardanelles. This rock, which contains a considerable amount of potassium, has been named a latite by Ransome.

THE TUFFS OF OROVILLE.

Along the foothills from Bear River to Feather River a series of light-colored tuffaceous rocks are exposed in places, although the formation is generally covered by later Quaternary gravels or by the red soil of the valley. The first exposures were seen a few miles north of Bear River, near the south end of an area of andesitic tuff which here spreads out in front of the most westerly exposures of greenstone. In a bank 20 feet high is shown 8 feet of sandy clay, which is covered by 4 feet of tuffaceous material containing pumice with small foils of biotite; this in turn is covered by 9 feet of volcanic sand. These deposits, which are distinctly later than the andesite mentioned above, are also present along Yuba River a short distance below Browns Valley, where they form the bedrock of the gravel which is dredged at that point. They also occur underneath the Quaternary gravel on the rolling bare foothills in front of Browns Valley Ridge. Similar deposits are seen in exposures 10 or 12 feet high on Honcut Creek; finally near Oroville they are extensively developed and form the low flat-topped hills which flank the river

on the south side for a distance of 8 miles below Oroville; these hills are covered by thick Quaternary gravels and gradually merge to the south into the gravelly plains about Palermo. The tuff extends under the present alluvium of Feather River and forms the bedrock of the area now worked so extensively by dredging. It is a compact light-brown material, containing in places pebbles of metamorphic rocks and also small white fragments of pumice which are found to consist of volcanic glass; locally these fragments are very small and the tuff looks more like a compact clay. Bore holes 80 feet deep have been sunk in it in the flood plain below Oroville without finding different material. On the road to Wyandotte from Oroville similar material outcrops in the low foothills underneath the Quaternary gravel up to elevations of about 400 feet. Benches of such gravel from 30 to 50 feet thick usually cover the tuff, so that as a rule the only satisfactory exposures are found along the bluffs. The bedrock relations at Oroville indicate that this series was deposited on the even slope of the older (Neocene) formations, before the modern canyon of Feather River had been excavated but after the earlier Ione formation had been greatly eroded. (See fig. 5, p. 90.)

The pumice containing biotite foils which is so common in these tuffs is entirely unknown in the andesitic flows which descended along the slope of the Sierra Nevada. On the other hand, acidic eruptive rocks like those contained in the tuffs are present in the extinct volcano of the Marysville Buttes, which lies in the center of the valley only about 25 miles to the southwest or west of these tuff areas, and it is confidently believed that the tuffs represent the accumulations of ash showers from this volcano, especially as the prevailing southwesterly winds would drive them in just this direction. It is thought that these eruptions took place somewhat later than the andesitic eruptions of the summit region.

QUATERNARY GRAVELS.

Along the valley border the Neocene terranes are overlain by an extensive series of poorly consolidated gravels, sands, and clays; the exposures rarely attain 100 feet in height and usually consist of low bluffs along the river courses and rolling hills between them. A distinct erosional unconformity separates these beds from the Ione formation, the andesitic flows, and the tuffs of Oroville. This indicates that before the deposition of the gravels the shore line had moved farther out into the valley, and this conclusion is confirmed by the fact that gold has accumulated underneath the gravel on the surface of the tuffs and the Ione formation many miles to the west of the present bedrock exposure. After the deposition of the tuff beds of Oroville there followed, however, a general rise of the base-level which resulted in the deposition of beds of gravel and sand, the gravels predominating. The highest gravels are found at elevations of 350 to 400 feet. Along the main rivers this epoch of gravel deposition finds expression in a series of benches, such as those on both sides of Oroville. The lowest bench lies 30 feet above the river at an elevation of 160 feet. Above this there are two broad benches which have elevations ranging from 340 to 430 feet. The conditions are somewhat similar, though the benches are less well defined, along Yuba River and Bear River. At the mouth of the canyon of American River broad benches spread to the north and south at elevations of 100 to 250 feet.

The Quaternary gravels are in general thoroughly washed and consist mainly of quartzite and other highly siliceous pebbles. They have probably been formed by the reworking of older gravels, a process during which the softer rocks were entirely disintegrated. According to Turner these siliceous gravels illustrate in a striking degree the law of the survival of the fittest. At many places the Quaternary gravels are gold bearing and have been washed with profit, especially where underlying tuffaceous rocks have proved effective gold catchers.

In many of the folios on the gold belt (see fig. 1, p. 10) the Quaternary gravels have been considered as having been deposited in a lake, but the probability is that they should rather be considered of fluviatile origin.

Since the deposition of the flood plains described above the base-level has been lowered and the rivers, at the edge of the valley, have deepened their canyons, mostly by reexcavating

old detrital deposits, until their beds now lie about 100 to 250 feet below their old flood plains. The alluvial deposits of the present rivers are not extensive near the mouths of the canyons, but a short distance below begin to widen and finally merge into the large alluvial areas of the Great Valley.

It is assumed that the deposition of the Quaternary bench gravels was contemporaneous with the main epoch of erosion which excavated the present canyons and that the glacial epoch which has just closed in the high Sierra corresponded with the deposition of the present alluvium. During the erosion of the canyons of the range to depths reaching 4,000 feet and the accompanying removal of enormous masses of the covering Tertiary volcanic formations an amount of material has been transported into the valley which far exceeds that moved during the whole period of the Tertiary auriferous gravels. There is no evidence of this tremendous mass of detritus in the present valley, for the bench gravels described above can account for only a small part of it. There are no débris fans in the valley corresponding to those resting in front of the desert ranges in the Great Basin, for instance. It is difficult to avoid the conclusion that the Great Valley has subsided to a corresponding degree since the beginning of this epoch of erosion. At first glance it looks as if the load had been removed from the range to the valley which has sunk under its weight.

It has been assumed that the close of the volcanic period marks the close of the Pliocene and that the erosion of the canyons falls into the early Quaternary, while the glacial epoch would correspond to the late Quaternary. The paleontologic evidence tends to show, however, that the volcanic epoch lay within the Miocene, and this would permit the great erosion of the canyons, the Sierran period of Le Conte, to occupy the time of the Pliocene and the Quaternary. If the close of the volcanic epoch should be removed to the beginning of the Pliocene, it would give a more adequate length of time for the accomplishment of the gigantic work of erosion which is manifested in the deep trenches now scoring the flanks of the range.

SUMMARY OF GEOLOGIC EVENTS ALONG THE VALLEY BORDER.

The geologic history of the valley border from late Cretaceous time to the present day may be summed up briefly as follows:

1. Pre-Chico (late Cretaceous) erosion.
2. Chico transgression. Shore line moves eastward to present elevations of 300 to 2,000 feet.
3. Post-Chico erosion. Shore line moves west of present valley border.
4. Tejon (Eocene) transgression. Shore line moves eastward at least to present elevations of 800 feet.
5. Post-Tejon erosion. Shore line moves west of present valley border.
6. Ione (Miocene) transgression. Shore line moves eastward to present elevations of 1,000 or 1,200 feet.
7. Post-Ione erosion.
8. Deposition of interrhyolitic shore gravels.
9. Postrhyolitic erosion.
10. Deposition of interandesitic shore gravels.
11. Deposition of volcanic ash beds of Oroville.
12. Important period of erosion (Pliocene and Quaternary)—Sierran period of Le Conte. Excavation of canyons of the range.
    (a) Shore line retires permanently west of the valley border.
    (b) Deposition of extensive fluviatile gravel beds up to elevations of 450 feet.
    (c) Deepening of stream beds along valley border by 100 to 300 feet.
    (d) Deposition of lower bench gravels.
    (e) Deposition of present alluvium.

THE SIERRA NEVADA.

TERTIARY RIVER GRAVELS AND VOLCANIC ROCKS.

Accumulations of gravel are found along almost all the Tertiary river channels now exposed by erosion along the slope of the range. The only exceptions to this rule are the upper parts of the stream courses near the present divide, where the grade evidently became too steep for the accumulation of such detrital deposits. The areal extent of the gravels, as shown on a geologic map, would not be large. Except those at a few places along the deep longitudinal

depression which existed on the middle slopes between Forest Hill, in Placer County, and North Bloomfield, in Nevada County, the areas would not show prominently on a map of small scale such as Plate I (in pocket). The andesitic and rhyolitic flows cover the largest parts of the gravels.

The Tertiary deposits comprise several epochs which are distinguished in the following paragraphs. (See also fig. 2.)

PREVOLCANIC DEPOSITS.

Deep gravels.—The deepest trough-shaped depressions (Pl. V, *B*) in the drainage basin of the Tertiary Yuba River are usually filled to a depth of 50 to 200 feet by coarse gravels which ordinarily have been cemented so that they can not be readily washed without previous crushing. In the main channels the pebbles are large and well rounded. They range in size up to cobblestones and even bowlders several feet in diameter (see Pl. XXI, *B*; p. 144), but all of them, unless subsequently decomposed, have a smooth or polished surface. They consist mainly of the rocks of the older series; quartz forms a part of the pebbles but rarely predominates. There is no clay and the cementing material between the pebbles consists of coarse sand. The coarse and bowldery character of these lower gravels is especially emphasized in the smaller streams or in places where the large stream beds contract in passing through bars of hard rock. Conspicuous examples of such conditions are furnished by the Cherokee mine, in Butte County, and the Polar Star mine, in Placer County. The deposits evidently originated in a stream of fairly strong grade and large volume. In the southern Tertiary rivers—for instance, that finding its outlet from Vallecito to Valley Springs, in Calaveras County—the deep gravels are

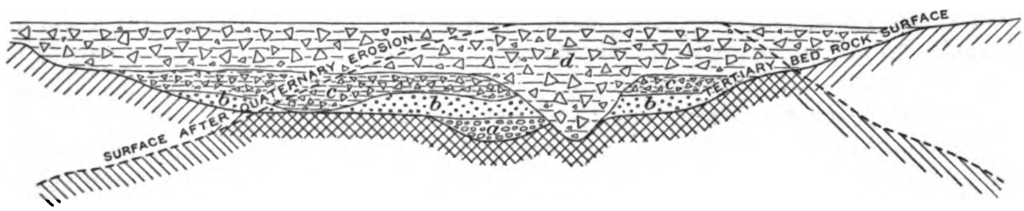


FIGURE 2.—Schematic representation of the four principal epochs of Tertiary gravels in the Sierra Nevada. *a*, Deep gravels (Eocene); *b*, bench gravels (Miocene); *c*, rhyolitic tuffs and interrhyolitic channel; *d*, andesitic tuffs and intervolcanic channel.

much thinner than along the Tertiary Yuba. In many places they are entirely absent. No fossils have been found in the deep gravels except at one place near Susanville, where an Eocene flora was discovered by Diller. It is likely that these gravels are of Eocene age, and some of them along the Tertiary Yuba River may even be Cretaceous.

Bench gravels.—Covering the deep gravels and attaining a maximum thickness of 300 feet, the bench gravels are spread out, in places to a width of 1 or 2 miles, on the sloping shelves on both sides of the deepest troughs (Pl. V, *B*). These gravels usually contain much quartz and are much more admixed and interstratified with finer sediment than the deep gravels. The pebbles are also smaller and always, except close to the headwaters, well rounded and polished. (See Pl. XXIV, *B*, p. 150.) These gravels indicate an epoch when the streams became overloaded; the extensive deposition which resulted from the overloading and the lessening of grades created broad flood plains over which the rivers flowed in changing channels. The distinction between the deep gravels and the bench gravels is much more marked along the Tertiary Yuba River than along the streams to the south. Different conditions prevailed along Jura River, which flowed northward and found its outlet at a point west of Susanville. In the lower part of this stream, from the vicinity of Taylorsville to Mountain Meadows, the lowest deposits consist of beds of sand, in some places with lignite; above this lie about 100 feet of coarse auriferous gravels. Near the old outlet the thickness of the prevolcanic deposits increases greatly. According to Diller 400 feet of sand is exposed, and this is covered by heavy prevolcanic gravels.

As more fully stated in chapter 3, the age of the bench gravels is believed to be Miocene, the determination being based on large collections of fossil leaves.

VOLCANIC AND INTERVOLCANIC DEPOSITS.

Rhyolitic tuffs.—Sweeping down the main river channels from the vents in the high Sierra, flows of white rhyolite, accompanied by large masses of rhyolitic tuff, of clayey and sandy character, covered the bench gravels. These rhyolitic flows attain on the middle slopes a maximum depth of about 200 feet; higher up they are much heavier. Much of this tuff is in the mining region designated as pipe clay or chalk.

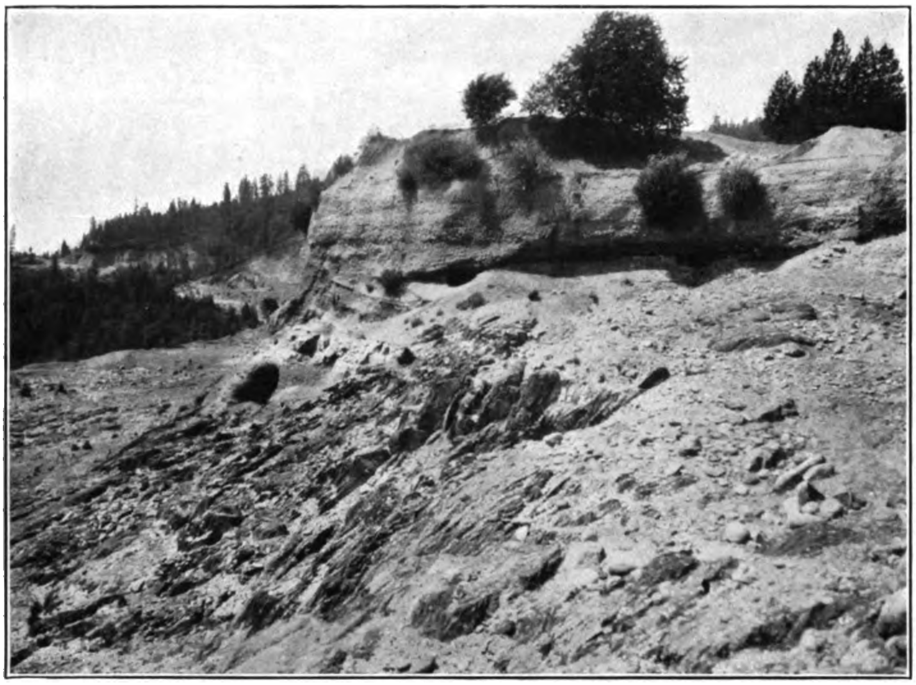
Gravels of the rhyolitic epoch.—The rhyolitic flows had the effect of damming many lateral streams, thus causing immediately accumulations of gravels, clay, and sands. During the intervals between the rhyolitic eruptions the streams cut down new channels in the soft material and accumulated masses of gravel in their new beds. All these detrital masses of gravel, sand, and clay, generally of a finer character than the bench gravels and usually containing rhyolitic pebbles, are designated as the "gravels of the rhyolitic period," or "interrhyolitic gravels." In many places, such as Nevada City, Nevada County, and the Long Canyon divide, Placer County, the rhyolitic gravels attain a thickness of several hundred feet.

Andesitic tuffs and tuffaceous breccias.—After the close of the rhyolitic eruptions the volcanoes along the summit of the range began to emit andesitic lavas and successively a great number of thin flows poured down the river valleys. Only near the summits, however, are massive flows and breccias found. (See Pl. VI.) Over the greater part of the slope the eruptions assumed the form of mud flows, at first as sandy and clayey masses but later mixed with a great quantity of larger angular or subangular fragments of hornblende and pyroxene andesites, so that at last the greater part of the slope, except the higher ridges, was covered and the rivers were forced to seek entirely new channels. The thickness of the andesitic flows is usually less than 200 feet along the valley border; on the middle slopes the average thickness is about 500 feet; and high on the range, in the Truckee quadrangle, for instance, a thickness of 1,000 to 1,500 feet was attained.

Gravels of the andesitic epoch.—The epoch of the andesitic eruptions extended over a considerable time interval and between the various flows the rivers continued their work and deposited gravels. The tilting of the slope of the Sierra Nevada evidently began at the close of the rhyolitic epoch, for the interandesitic streams possessed an exceedingly active power of erosion. Sharp V-shaped canyons were cut through the older beds and in some places even down into the solid bedrock to a depth of about 100 feet. The new channels differed considerably in direction from the prevolcanic streams, but most of them still followed the same general valleys. In the bottom of these sharply cut channels a few feet of gravel accumulated along stretches with less grade. These are the "gravels of the andesitic epoch," or "the interandesitic gravels."

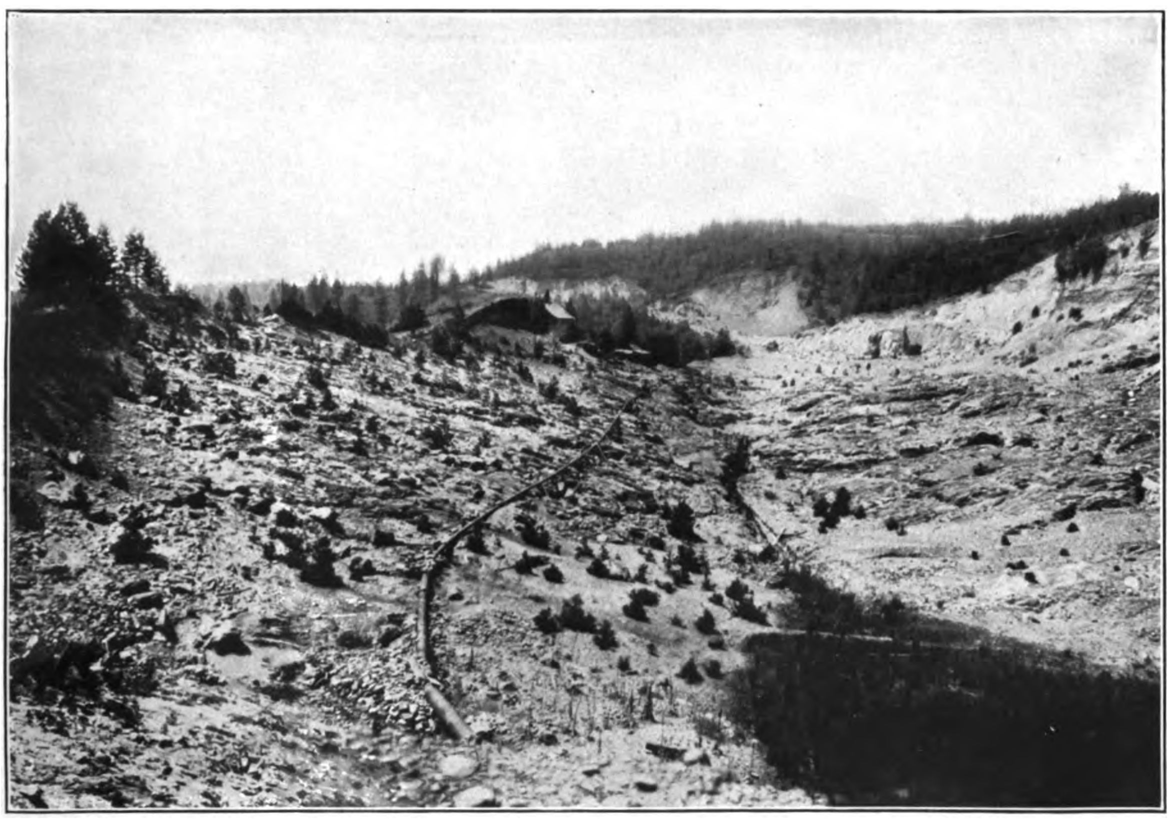
Although evidences of such an epoch of erosion are found nearly everywhere along the slope, they are conspicuous only in certain places where erosion was deep and gold has accumulated. In the main drainage area of the Tertiary Yuba River the outlet must have been through the narrow transverse channel from French Corral to Smartsville, and deep interandesitic channels are not found except high up toward the divide near Forest City and other places in Sierra County. On the Forest Hill divide, however, the tilting effected an overflow directly down the slope by way of Peckham Hill, and in consequence the interandesitic erosion is particularly well shown in this vicinity.

Along the Tertiary Calaveras River the interandesitic channels are generally absent, except in one of the tributary systems near Mokelumne Hill. In this drainage basin, however, the conditions were similar to those on the Forest Hill divide; an outlet directly down the slope was established for a short time before the last flow, and this is marked by the sharply eroded channel underlying the Tuolumne Table Mountain. During this brief epoch a stream was established which had its source near the Dardanelles and its outlet at Knights Ferry, on the Stanislaus, and which squarely intersected the old Tertiary Calaveras River just east of Vallecito. With the last flows, however, this channel was abandoned and the course of the present Stanislaus River was laid out.



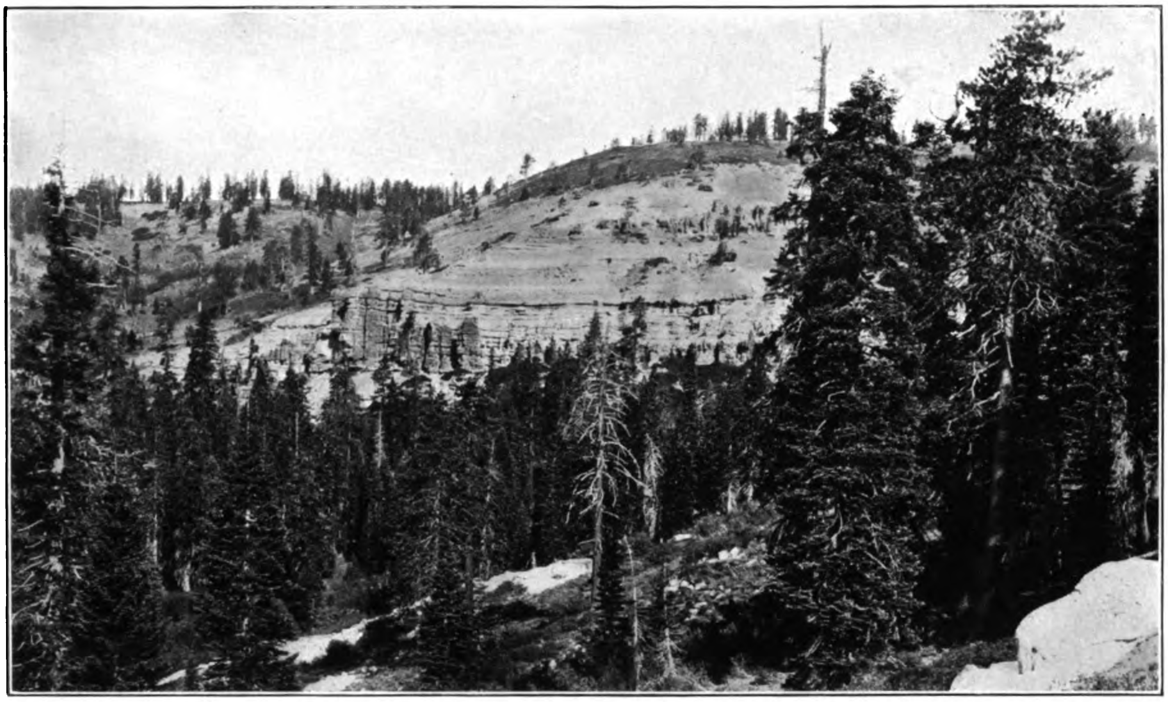
A. BENCH GRAVEL ON NORTH RIM OF DARDANELLES CHANNEL, PLACER COUNTY.

Photograph by J. M. Boutwell. See page 150.



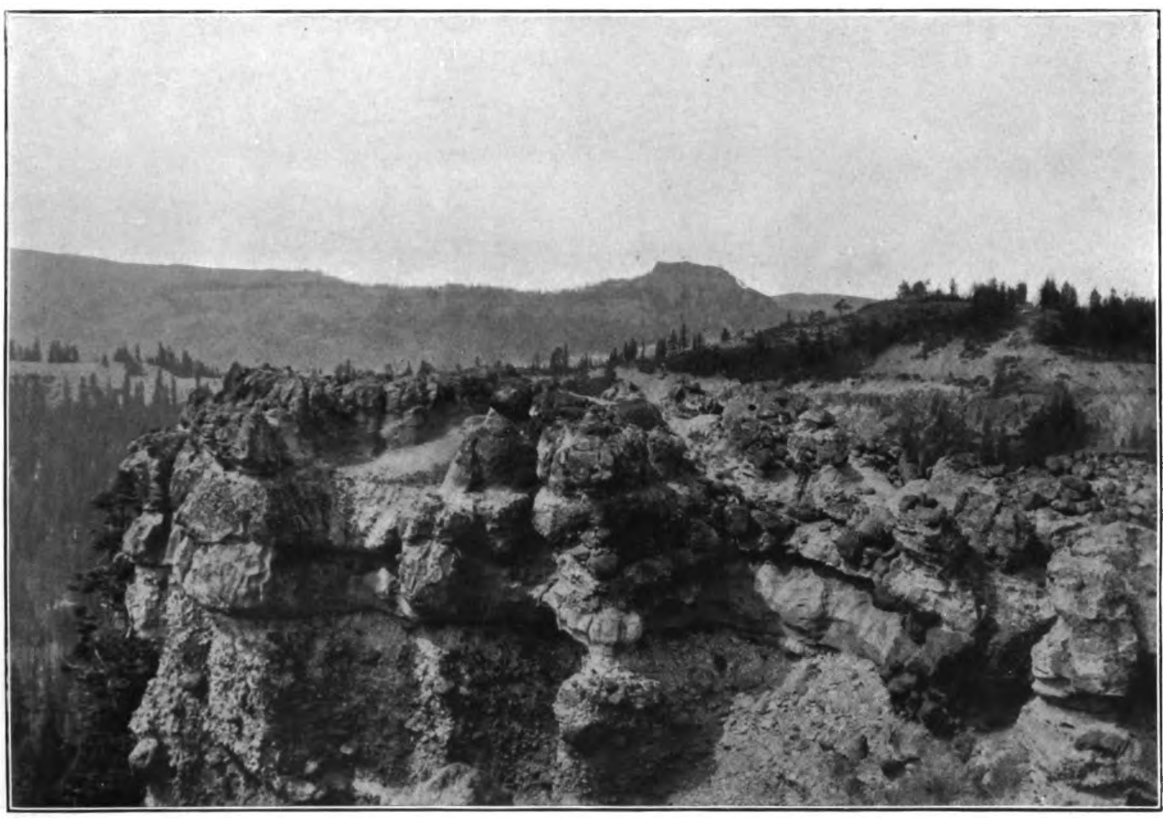
B. HYDRAULIC PIT IN DARDANELLES MINE, FOREST HILL, PLACER COUNTY.

Bedrock of entire deep channel laid bare by mining. In the distance is seen a rhyolitic channel crossing the early Tertiary channel. Photograph by J. M. Boutwell. See page 150.



A. HILLS OF ANDESITIC TUFF-BRECCIA 1½ MILES NORTH OF BLOODS, BIG TREES QUADRANGLE, CALAVERAS COUNTY.

Photograph by H. W. Turner. See page 32.



B. BLUFF OF ANDESITIC BRECCIA NEAR MOUNT LINCOLN, PLACER COUNTY, AT SUMMIT OF RANGE.

Devils Peak in the background and Snow Mountain just beyond extreme left. Photograph by J. C. Hawver. See page 32.

TERTIARY AND QUATERNARY IGNEOUS ROCKS.

The occurrence and distribution of the Tertiary and Quaternary igneous rocks have been outlined in a broad way on pages 25–27. It is not intended to present a full petrographic description of these rocks, but their succession will be mentioned in somewhat greater detail in the following paragraphs. Much information on this subject is found in the writings of Turner,[1] who also quotes a considerable number of analyses.

Within the parts of the range here considered the following succession of late igneous rocks has been recognized:

1. Rhyolite, massive and fragmental.
2. Older basalt and latite, massive.
3. Hornblende-pyroxene andesite; tuffs, breccias, and smaller amounts of massive rocks.
4. Pyroxene andesite, fine grained and massive.
5. Doleritic basalt, coarse grained and massive.
6. Basalt, massive.

The last division, that of the normal basalt, belongs in the Quaternary period.

Rhyolite.—The rhyolitic flows occupy small areas, chiefly following the Tertiary River valleys. The massive rocks are of light-gray to pink color and of fine grain and show small crystals of quartz and sanidine in a streaky and glassy groundmass. Rarely a little brown mica appears. In the upper regions the rhyolite is massive but has a tendency toward changing into tuffaceous forms and it is often difficult to decide whether a particular specimen should be considered as a massive rock or a tuff. Farther down the slope the tuffs grade into light-colored or white sandy and clayey beds (Pl. XXIV, *A*, p. 150). According to numerous analyses given by Turner the rhyolites are typical rocks of their kind, the percentage of silica ranging from 70 to 73, that of potash from 4 to 5.50, and that of soda from 1 to 3.50; the lime is about 1 per cent.

The rhyolitic volcanoes were scattered along the summit region from Sierra County to Tuolumne County. Important foci of eruption are noted at Haskell Peak, in Sierra County; at Summit, in Nevada County; near Silver Lake, in Eldorado County; and probably at several points in Tuolumne County in the Dardanelles quadrangle. The two most important points of eruption were those at Summit and near Silver Lake, for they furnished the material which flooded the Tertiary streams in the Colfax and Placerville quadrangle. Along the western slope of the range and along the eastern escarpment few rhyolitic eruptions took place. It is not certain, indeed, whether there is a single locality of eruption along the western slope, except possibly at a place near Jackson Butte, north of Mokelumne Hill, where Turner reports a peculiar craterlike depression, filled with rhyolitic tuff.

Older basalt.—In Butte and Plumas counties there are extensive flat-topped ridges covered by a dense black basalt which at many places is capped by andesitic flows. Oroville Table Mountain belongs to this group, and further exposures are seen near Mount Ingalls and thence down the slope in the direction of Oroville. These rocks contain about 51 per cent of silica, 4 per cent of magnesia, 2 per cent of potash, and 3 per cent of soda. They are high in lime and iron. The principal place of eruption was undoubtedly in the northern part of the Downieville quadrangle, but there are some indications that this or a similar rock was erupted in the vicinity of the Table Mountain at Oroville.[2]

The latite of Tuolumne Table Mountain belongs in the same class, but contains more potash; this substance is mainly concentrated in the groundmass.

Turner believes that this early basalt followed the rhyolite in time of eruption. The latite is of interandesitic age and originated in the summit region of Tuolumne County.

Andesite.—The general character of the andesitic flows and their associated beds of volcanic conglomerates and sands has already been mentioned. By far the greater part of the andesite

[1] Turner, H. W., The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 484–495; Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 540–543, 613–616; The age and succession of the igneous rocks of the Sierra Nevada: Jour. Geology, vol. 3, 1895, pp. 385–414.

[2] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 543.

toccurs in the form of a tuffaceous breccia in numerous superimposed flows. These breccias mus have issued from fissures near the summit of the range and were, either before their eruption or at the time of issue, mixed with enormous quantities of water, forming mud flows sufficiently fluid to spread down the slope for distances of 50 or 60 miles. The derivation of the water and the exact mode of eruption are difficult to determine. In endeavoring to explain them Turner has described some similar mud flows from volcanoes active within recent time in Java and Japan.[1]

Toward the summits the breccias gradually lose their stratified character and become more firmly cemented. Over large areas in the Truckee quadrangle the andesitic masses consist of breccias containing numerous dikes and necks of massive andesite.

The andesite is a rough and porous rock of dark-gray to dark-brown color. Phenocrysts of plagioclase, augite, and hypersthene are always present, and in many rocks hornblende appears as small black needles. The groundmass has a structure varying from glassy to very fine grained holocrystalline. Biotite is of very rare occurrence. Olivine is present here and there in the pyroxene andesites, which locally merge into fine-grained varieties allied to basalts. Andesites containing mainly hornblende occur in places and are of lighter-gray color.

The analyses show the andesites to be an intermediate rock, with silica ranging from 55 to 67 per cent, from 5 to 8 per cent of lime, 1.5 to 2.5 per cent of potash, and 3.5 to 4.5 per cent of soda. Trachytic modifications are rare, though Turner[2] mentions some rocks containing biotite which carry as much as 5 per cent of potash. The rocks thus correspond fairly well to the granodiorites among the older granular rocks. On the whole the andesites, however, contain somewhat less silica and more calcium.

The andesitic volcanoes were mainly located along the crest of the Sierra—in fact, almost continuously from Thompson Peak, west of Honey Lake, down to latitude 38° 10′. Farther south the eruptions diminished greatly in intensity. In the Downieville quadrangle important eruptive centers are found at Mount Ingalls, Grizzly Peak, and the group of old volcanoes around Mount Fillmore, near the line between Plumas and Sierra counties. The Mount Fillmore locality is farther west than most of the others, but still lies in the higher part of the range. North and south of Sierra Valley were numerous foci of eruption. Along the first summit of the range west of Lake Tahoe the greatest number of vents are found. Beginning at Webber Lake on the north, they include Mount Lola, Castle Peak, Mount Lincoln, Tinker Knob, Mount Mildred, and Twin Peak. The andesitic masses here in places attain a thickness of 2,000 feet. An interval follows in the northern part of the Pyramid Peak quadrangle where no important volcanoes were located, but they appear again in full force in Alpine County. Round Top, attaining an elevation of 10,430 feet, and the adjacent peaks were the sources of the enormous flows which covered a large part of Eldorado County. Still another volcanic complex with many eruptive vents is that situated in the western part of Alpine County, near Markleeville, which culminates in Highland Peak and Raymond Peak (Pl. VII, *A*), the former almost reaching 11,000 feet. The total thickness of the volcanic flows in this locality is as much as 4,000 feet.

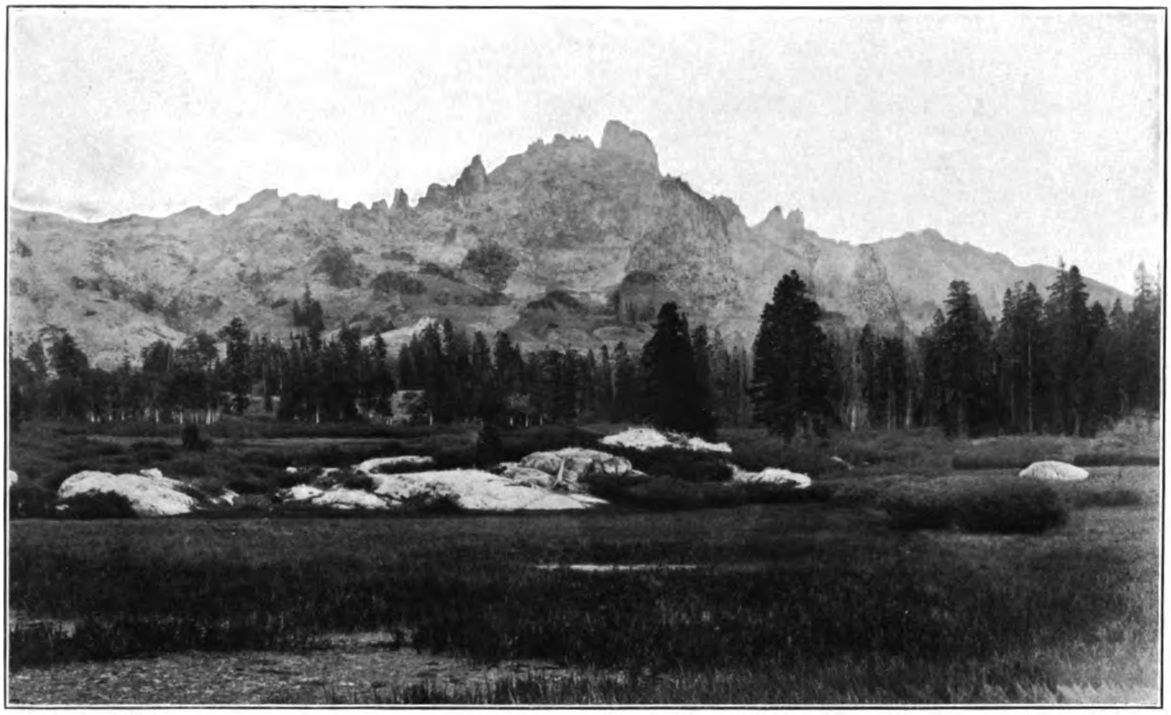
The andesitic eruptions continued south of Alpine County, and one of the main vents was located in the picturesque bluffs known as the Dardanelles.

Along the eastern range of the Sierra Nevada, east of Lake Tahoe, there are a few smaller bodies of eruptive rocks. At its north end, however, southwest of Reno, another large andesitic volcano poured forth lavas which extend between the Truckee River canyon and the Washoe Valley. In the region extending northward from Lake Tahoe to Sierra Valley enormous andesitic eruptions took place, and the products of these volcanoes are now piled up as high mountains, among which Mount Pluto nearly attains 9,000 feet.

None of the craters of these volcanoes are preserved, and at the time of their greatest activity they may have reached a height of several thousand feet above the present summits.

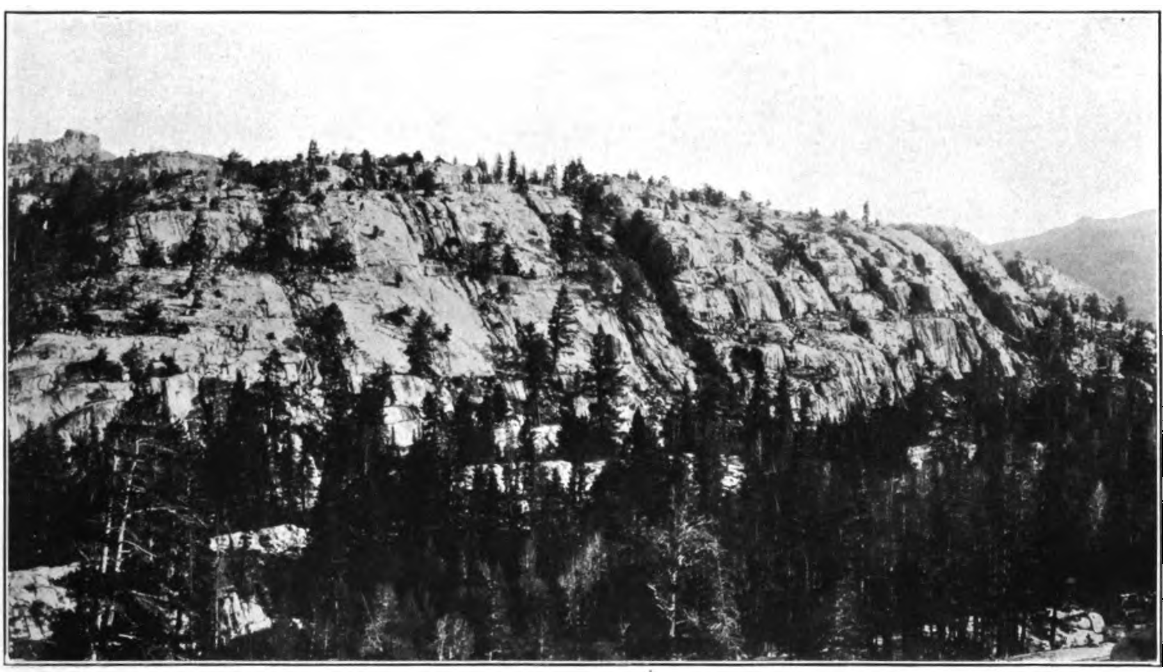
[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 537–539.

[2] Idem, p. 696.



A. WEST SPUR OF MOUNT RAYMOND FROM INDIAN VALLEY, MARKLEEVILLE QUADRANGLE, ALPINE COUNTY.

Showing rough character of ridges of andesite. Photograph by H. W. Turner. See page 32.



B. VERTICAL SHEARING IN GRANITE NORTH OF CHARITY VALLEY, MARKLEEVILLE QUADRANGLE, ALPINE COUNTY.

Photograph by H. W. Turner. See page 46.

Comparatively few andesitic vents are known on the long western slope of the range. At two places in the Jackson quadrangle in Calaveras County, known as Golden Gate Hill and Jackson Butte, small eruptions of andesite took place. The products of these vents are distinguished from the surrounding tuff breccias by their massive structure.

Fine-grained pyroxene andesite.—In the Downieville and Bidwell Bar quadrangles eruptions of a dense fine-grained gray lava, which usually weathers wrth strong lamination, took place in several localities. This fine-grained andesite covers the tuffaceous breccia at Table Mountain near Forest City, on the ridges north of Downieville, and at several places farther west. This rock is not far removed from a basalt but contains from 57 to 67 per cent of silica.

Doleritic basalt.—The coarse basalts of Mount Ingalls are believed by Turner to belong to early Pleistocene time. This lava, which from the analysis given appears to be a normal basalt, is not found elsewhere.

Quaternary basalts.—The Quaternary plagioclase basalts are normal rocks of their kind and usually contain olivine. They were erupted from numerous vents during the period of erosion which followed the eruption of the andesite. Some of them lie on the slopes of the canyons, their position indicating that they were erupted before the present depth had been attained. At the north end of the range, around Lassen Peak, the basaltic rocks cover enormous areas and many of the craters are still preserved. These basalts extend as far south as Susanville. In the Truckee quadrangle, 40 miles farther south, the next large eruptions of basalt took place. They form comparatively thin sheets which flowed down into the center of Truckee Valley over the eroded surface of the andesite. Farther south small areas of basalt occur here and there over the western slope of the Sierra Nevada. Such local vents are found at several places in the Bidwell Bar quadrangle, at two places in Colfax quadrangle, west of Tells Peak in the Pyramid Peak quadrangle, and north of Mokelumne River in the Big Trees quadrangle. The areas are, however, insignificant.

Quaternary rhyolite.—The Quaternary basalt closes the series of eruptions in the Sierra Nevada proper, but it is interesting to recall that immediately east of the eastern scarp of the range south of Mono Lake there are a number of rhyolitic vents with well-preserved though small volcanic cones, which evidently were active during Quaternary time.

TERTIARY DRAINAGE SYSTEM.

General features.—The drainage lines of the Tertiary range corresponding to the Sierra Nevada extended in two directions. The first and more important was toward the west and is represented by at least five main streams that emptied into the gulf which then occupied the Great Valley. The second direction of drainage was toward the north and is represented by the stream to which the name Jura River has been given. This headed near Meadow Lake, in Nevada County, in the present summit region, and, taking a course slightly west of north, emptied a few miles west of Susanville into a bay of the sea or possibly into a lake, whose extent and relation can not now be ascertained on account of the lavas that cover its sediments to the north. At any rate, the conditions of discharge were radically different in the two basins, for while on the west side, toward the Sacramento Valley, the lowest gravels in the troughs of the rivers are coarse and compact, the lowest deposits in the most northerly reaches of Jura River were sandy and contain beds of lignite. Undoubtedly the eastern slope of the Tertiary range was also drained by a system of rivers, but the erosion has left little evidence of its character.

The present rivers of the western slope have generally a southwesterly direction corresponding to the present strongly pronounced slope of the range. Only in places, as in the upper part of Feather River, the middle Yuba River, and the uppermost part of Rubicon River, do they swing around to north-northwest, corresponding to the trend of the range. On Feather River this change of direction is due mainly to post-Miocene dislocations, but the courses of the Yuba and Rubicon were determined by the pre-Tertiary structure of the range.

The pre-Tertiary erosion emphasized the longitudinal structure, and this found expression in the courses of the ancient streams. The range had a much lower elevation than at present. Along the western margin the most prominent feature consisted in the abrupt greenstone ridges which from Mariposa County to Butte County followed the valley line. West of these ridges was a series of depressions which rose toward the east into an undulating plateau, and this was surmounted by a much higher ridge of flat-topped hills. In general the rivers broke through the greenstone ridges of the foothills in deep and rocky narrow valleys, but east of these ridges followed the central depression for longer or shorter distances. Farther upstream they again bent to the east, and their sources lay in the highest ridge of the Tertiary range.

From north to south, principal streams described below have been recognized on the western slope. (See Pl. I, in pocket; fig. 3, p. 40.)

Magalia channel.—A minor watercourse, which may be termed Magalia River, had its source in the northwestern part of the Bidwell Bar quadrangle and its outlet near Centerville, a few miles northeast of Chico. It flowed in a narrow canyon-like valley, rapidly widening at Centerville, where also large masses of gravel began to accumulate. Where exposed by mining operations near Magalia the channel was found to be filled with large bowlders and coarse sand, but the total depth of the prevolcanic deposits is probably not more than 50 or 75 feet.

Stream near Cherokee.—A somewhat similar but shorter stream is well exposed near the valley border at Cherokee. It shows the same characteristic of coarse, heavy bowlders resting in a well-defined though not V-shaped depression. The depth of this coarse gravel is 35 feet, and above it lies about 250 feet of sand and clay of the Ione formation.

Yuba River.—The Tertiary Yuba River was the largest of the streams draining the western slope. Its headwaters extended from the southern part of Plumas County southward to the dividing line between Placer and Eldorado counties on upper Rubicon River, a distance of about 60 miles. Its outlet, like that of its present equivalent, was near Smartsville, in Yuba County, at the valley border. Its course from North San Juan to Smartsville was southwestward for 20 miles; in this distance the united branches of the river broke through the greenstone ridges of the foothills in a valley, which, as can be seen at Smartsville and French Corral, had a depth of more than 1,000 feet. At Smartsville the bed of the Tertiary river was 200 feet above the present Yuba; at North San Juan about 700 feet. Coarse gravels to a depth of 170 feet filled this old trough and they are directly overlain by andesitic gravels and tuffs. Between French Corral and North San Juan the average thickness of the gravels was probably 200 feet.

Above North San Juan the river began to branch. An important tributary came down from the vicinity of Gibsonville, in Sierra County, by way of Camptonville. Heavy gravels of prevolcanic age are also present along this branch. At Poverty Hill the trough is filled to a depth of 25 feet with coarse gravel and large bowlders, above which lies a wide body of fine quartz gravel up to 120 feet in thickness. At La Porte the gravels are 130 feet thick and in the upper part consist of fine quartz gravels, in places mixed with thick beds of clay. Throughout the distance from La Porte to Smartsville the direction is southwest and the grade averages 100 feet per mile, though above La Porte it locally increases to 170 feet. The headwaters of the northern branch can not be traced to their sources, for at Gibsonville the channel is cut off by the canyon of the South Fork of Feather River, beyond which dislocations make further tracing impossible. Moreover, this locality is near a volcanic region whose eruptions have disturbed the old stream beds.

From North San Juan, or a short distance east of it, the trend of the river going upstream turned abruptly to the southeast and for 25 or 30 miles followed a longitudinal depression parallel to the crest of the range; this direction continued as far south as Forest Hill. In this old depression the heaviest gravels found within the range have accumulated. They were contributed by numerous streams from the east and apparently held back as if by a dam by the narrow canyon of the lower, transverse river course. At North Columbia the depth along the center of the channel is from 400 to 500 feet. The gravel in the deepest trough is coarse and in places bowldery, but the top gravels spread out over the benches are fine and more quartzose. At North Bloomfield, on a tributary that joined the main river at North Columbia, the deepest

gravel is 130 feet thick and this is capped by light-colored clay and sand interstratified with fine gravel; the thickness of these finer sediments may reach 150 feet. At You Bet and Little York the deep gravel is coarse and cemented and as much as 40 feet in thickness and is capped by up to 350 feet of fine gravel with some clay and sand. At Iowa Hill the sharply defined river trough is filled with 200 feet of coarse gravel covered by 200 feet of quartzose bench gravels of finer grain. These figures will suffice to give an idea of the great depth of the prevolcanic accumulations in this longitudinal trough.

Throughout the distance from Badger Hill upstream to Forest Hill the grade is very slight and locally reversed wherever the stream trended eastward of the line parallel with the slope of the range. In a distance of 30 miles the total fall was about 250 feet, which would average 8 feet to the mile. At Forest Hill the stream bends sharply to a general easterly direction and its upper course can be traced continuously for 40 miles to the vicinity of Castle Peak, just north of the Central Pacific Railroad. The thickness of the prevolcanic gravels rapidly decreases upstream, and near its headwaters the channel contains practically no detritus. The grade remains about 100 feet to the mile for most of the distance, but north of Soda Springs it rises to 200 feet to the mile, and the absence of gravel, the depth of the old canyons now filled by volcanic rocks, and the abrupt slopes all point to the fact that the actual source of the stream has been reached. The total distance along the course from Castle Peak to Smartsville is not less than 100 miles.

It has been stated that throughout the longitudinal portion of its course the river received numerous tributaries from the east. In all of these similar conditions can be traced—that is, gradual decrease of thickness of gravel and corresponding increase in depth of the valleys and slope of the declivities. For detailed information the reader is referred to another part of this report. One of the main tributaries can be traced upward by way of North Bloomfield, Moores Flat, and American Hill, and possibly as far up as Meadow Lake; but there is some doubt whether the upper part of this drainage did not rather belong to the northward-flowing Jura River. Laterals to this stream were received by way of Forest, Alleghany, and Minnesota; also by way of Relief Hill, Alpha, Omega, and Emigrant Gap.

Other tributaries to the main stream are traced upward from Dutch Flat to Remington Hill and from Dutch Flat to Shady Run and Blue Canyon. Lastly should be mentioned the tributary extending from Damascus to Michigan Bluff, which contains the "white channel" that has been mined so successfully at the Hidden Treasure mine. Throughout the course of the Yuba River of Tertiary time an absolute and unfailing dependence of the present grade on the direction of the ancient stream can be traced; wherever it trended southwest the grade is from 80 to 120 feet to the mile; where the trend was to the northwest the grade is diminished to low figures, rarely more than 30 feet to the mile and usually much less.

The most southerly branch of the river crossed the present Rubicon River and headed in Union Valley, in the Pyramid Peak quadrangle, not far from the South Fork of the present American River.

American River.—The Tertiary streams to the south of the Yuba occupied smaller drainage areas, their transverse direction was more emphasized, and the prevolcanic gravels found in the deepest depressions are of far smaller volume than those of Yuba River. In many parts of their courses there are only a few feet of such gravels and only exceptionally are they more than 50 feet in depth. On the other hand, the interrhyolitic gravels along these streams are of great extent and thickness.

The Tertiary American River had its outlet near Roseville, in Placer County, where the gravels have been mined at the Lee mine. Most of the accumulations in the low foothills have, however, been removed by erosion. In the upstream direction the course of the river trended to the northeast for 12 miles and then passed through the gap at Pilot Hill, whence it turned sharply southeast, following a longitudinal depression behind the high greenstone ridges of the foothills. This direction continued for 15 miles with slight grades of 18 to 55 feet to the mile, but most of the gravels within this distance have been eroded. Farther upstream, at Placerville, the course changed to a general easterly direction, which it followed up to the summit with

grades of 75 to 100 feet to the mile. The heaviest accumulations of gravels are found near Placerville. From Pacific, on the boundary line between the Placerville and Pyramid Peak quadrangles, eastward there are practically no gravels in the deepest depressions. The principal fork followed closely the present South Fork of American River with strong grades up to 160 feet to the mile. This part of the course was in a deep canyon, and where the Pyramid Peak Range was crossed the slopes to the north rose 3,000 feet within a distance of 3 miles The headwaters of this branch have been cut by the erosion of upper Truckee River, south of Lake Tahoe; the sources of this fork were in the Markleeville quadrangle, to the east, but its course east of the upper Truckee can not be traced with certainty.

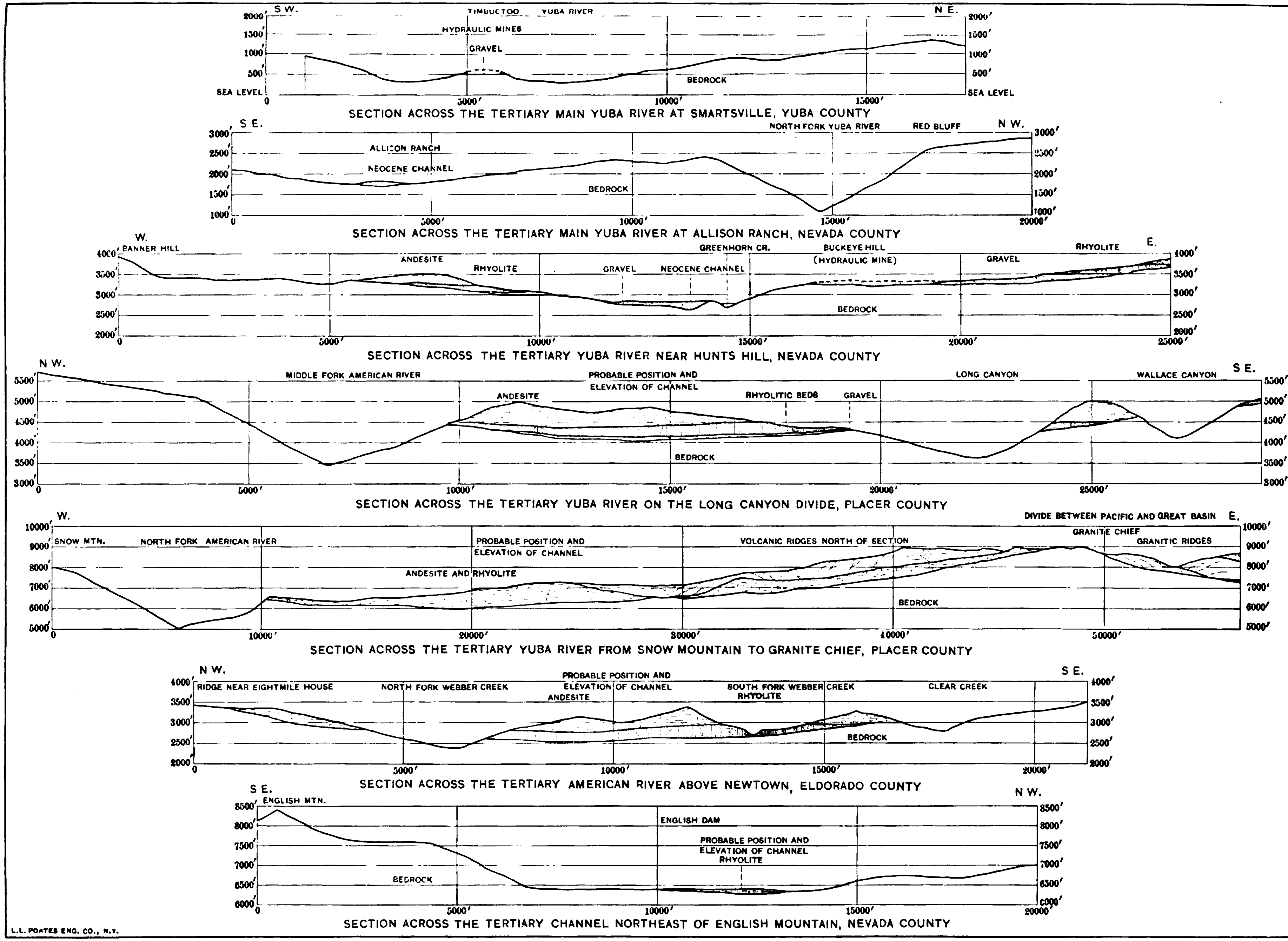
A southerly branch, not far distant from the principal fork, can be traced to its actual source just north of Round Top, a volcanic mountain rising to an elevation of 10,430 feet.

Mokelumne River.—The Tertiary Mokelumne River had a relatively small drainage area; it emptied into the gulf in the foothills of northern Amador County, which were reduced at this place to a more level surface, above which the hills rose to heights of not more than 400 feet. From Plymouth westward the gravels are eroded, except for a few small patches, but above Plymouth the course is well marked and can be traced upstream in a nearly easterly direction along the boundary line of the Placerville and Jackson quadrangles; its headwaters are found near Mokelumne Peak, which attains an elevation of 9,371 feet. Two minor tributaries join the river from the north, one descending from Grizzly Flat toward Indian Diggings and the other a few miles farther east by way of Pi Pi Valley and Fort Grizzly. Here again the gravels in the upper stream courses are thin or absent and the greatest thickness is accumulated near Oleta, at elevations of about 2,000 feet.

Calaveras River.—The Tertiary Calaveras River formed a stream of larger drainage area than the two just mentioned. Its outlet was at Valley Springs, in a gap between high greenstone ridges on the north and the conspicuous ranges of the Bear Mountains to the south. West of Valley Springs the deeper gravels are completely hidden by thick masses of the Ione formation (Miocene) and overlying Tertiary shore gravels. Upstream the river bent sharply behind the greenstone ridges and followed for 15 miles a deep depression east of the Bear Mountains by way of San Andreas and Angels. In this distance the grade is only 28 feet to the mile and the interrhyolitic gravels are in places 200 feet thick. A smaller but rich tributary came down from the north by way of Jackson and Mokelumne Hill. A second tributary descended from the north, following the so-called Fort Mountain channel and joining the main stream a few miles to the south of San Andreas. A short distance to the east of Angels, at Vallecito, thick gravels, principally rhyolitic, accumulated in a basin inclosed by high bedrock hills. At Vallecito the Tertiary channel lies about 1,200 feet above the deep canyon of the North Fork of Stanislaus River. The Tertiary channel crossed this fork and then assumed a general easterly direction. A short tributary joined it from the south, heading in the deep basin at Columbia, in Tuolumne County. Above Vallecito the course of the Tertiary river may be traced by means of the depressions in the volcanic areas, as indicated on the map (Pl. I, in pocket), but the channels contain little or no gravel and are generally barren; the ultimate headwaters lie in the Dardanelles quadrangel and have not been traced.

Cataract River.—During the interandesitic epoch a drainage channel was established for a short time which followed the slope of the Sierra in a general southwesterly direction across the Big Trees quadrangle from Clover Meadow by way of the Calaveras Grove and Douglas Flat. It crossed the Tertiary river at Vallecito and the present Stanislaus River has intersected it at Parrott Ferry. Its further course was by way of Sonora and thence down to its outlet at Knights Ferry on the Stanislaus, where it crossed the greenstone ridges of the foothills, probably utilizing a part of an older watercourse. With the last andesitic flows this stream and its valley became obliterated and the present course of the Stanislaus was laid out.

Tuolumne River.—The Tertiary Tuolumne River has been traced only through the Sonora and Yosemite quadrangles. The first remnant of its gravels is found at Chinese Camp, 8 miles south of Sonora. Most of its lower course is eroded, but the bedrock relations show that it must have approximately followed the course of the present Tuolumne River. In this latitude



CROSS SECTIONS SHOWING SLOPES OF TERTIARY VALLEYS.

See page 37.

the andesitic flows had greatly decreased in volume, and it is natural that the present rivers should have in the main followed the old Tertiary valleys. A number of gravel deposits which clearly indicate the Tertiary channel are found on the south side of Tuolumne River and about 1,500 feet above it in the vicinity of Colfax Gate, where the present river clearly follows the pronounced southward bend of the Tertiary stream. The prevolcanic gravels have in places a thickness of 100 feet. In the Yosemite quadrangle the channel continued with a nearly east-northeast direction by the way of Hetch Hetchy Valley, Tiltill Valley, and Piute Creek, as traced by Turner. The Neocene river occupied here a rugged canyon, which, however, was not nearly so deep as the present canyon of the Tuolumne. The outline of the old valley, now filled with lava, is well shown in Plate XXVIII (p. 218). The ultimate headwaters to the east were probably near Mount Dana. The grade in the upper part averages 136 feet to the mile; in a part of the lower course between Colfax Gate and Big Humbug Creek it is only 47 feet to the mile; in this stretch the channel had a northwesterly direction. Below Big Humbug Creek its probable course to Chinese Camp necessitates a grade of 93 feet to the mile.

TERTIARY PREVOLCANIC SURFACE.

The evidence available shows conclusively that at the time when the oldest gravels, probably of Eocene age, began to accumulate the Sierra Nevada was a mountain range as distinct, if not as high, as at present. The rivers headed near the points where the corresponding modern rivers begin now, in a region of lofty peaks and ridges. In geologic literature it has been repeatedly stated that the Tertiary surface of the Sierra Nevada is that of a peneplain, a conclusion absolutely at variance with the opinions of those who have actively studied the range. The origin of this theory of a peneplain is probably to be traced to a hasty view of level lava flows obtained during the descent from the summit to the Sacramento Valley along the Central Pacific Railroad. How difficult it is to eradicate this conception may be realized from a recent statement[1] by a Californian geologist that "these dead rivers, which must have run on a low plain not far above sea level, are now found high up in the Sierra Nevada with their channels buried deeply under later lava flows."

Our knowledge of the Tertiary and pre-Tertiary physiography of the range is mainly confined to its western slope; the eastern slope has been so changed by orogenic movements, principally faulting, that it is difficult to draw a definite conclusion as to its topographic features, but it is probable that before the dislocations along the great fault system began the range had a rather long easterly slope corresponding to that on the west.

The Tertiary topography of the western slope consisted of four units. Along the valley line extended a number of abrupt greenstone ridges attaining elevations of 1,500 to 4,000 feet. They are shown perfectly plainly in Yuba and Butte counties, for instance, by Browns Valley Ridge and the Oregon Hills, through which the Yuba River of Tertiary time broke through in a deep canyon. In Placer County an area of softer granodiorite reached the valley and in this vicinity—for instance, near Rocklin—the idea of a peneplain is more nearly realized than elsewhere. In Calaveras County the Tertiary Calaveras River broke through this barrier in a deep valley similar to that of the lower Yuba but much more abrupt; near San Andreas, for instance, these greenstone ridges rose 2,000 feet above the river in a distance of 3 miles. Still farther south this topography is even more prominently emphasized in the Penon Blanco Ridge and Bullion Mountain. Some typical sections across the old valleys are given in Plate VIII.

East of these high ridges there extended a series of longitudinal depressions which were in part followed by the rivers. In Tuolumne County is a well-marked valley of this kind between Colfax Gate and Big Humbug Creek, where the Tertiary river has an elevation of 2,800 feet, while 4 miles to the northeast the high slate ridges rose above it to present elevations of 4,500 feet. Another conspicuous longitudinal valley is that of the old Calaveras River, where at San Andreas the similar high slate ridges rose nearly 2,000 feet to the east of the river.

[1] Smith, J. P., Salient events in the geologic history of California: Science, new ser., vol. 30, 1909, pp. 346–351.

Still another instance of such relation is found between Placerville and Pilot Hill, but the best example is undoubtedly the great depression extending for 25 miles between Forest Hill and North Columbia, in the Colfax quadrangle.

To the east of these longitudinal depressions the country rose, at first rather sharply, to an undulating plateau which extended over a considerable space in the Sierra Nevada, usually at elevations of 3,000 to 5,000 feet, as well exemplified in the central part of the Colfax quadrangle and over a large part of the Big Trees quadrangle. This plateau-like character is naturally most emphasized in regions like the latter where granitic rocks prevail. A close examination will show that the Tertiary rivers had cut down well-defined broad valleys in this plateau, in general less than 800 feet in depth.

This plateau, as well as the longitudinal depression to the west of it, became flooded with thick flows of andesitic lavas which, of course, effaced to a great extent the pre-Tertiary topography, and these gently sloping flows give, when viewed from a distance, the impression of a peneplain. To an observer standing on a prominent point in the foothills—for instance, at Banner Hill, near Nevada City, or on a similar high point near Auburn—the topographic relations stand out very clearly. Looking toward the east he will see above the deep canyons of the modern rivers the broad, flat lava plateaus capping each succeeding ridge. Above these is a series of high peaks and ridges situated near the summit of the range. These ridges rise abruptly above the lava plateau and their summits attain elevations ranging from 7,000 to 10,000 feet. (See Pl. XIX, *A*, p. 134.) When the Tertiary rivers are traced back to this region they are found to occupy deep canyons and their gradients rise until their actual headwaters can be discerned.

An examination of the geologic map of the gold belt (Pl. I, in pocket) will show that this ancient region of the highest bedrock peaks does not exactly coincide with the present summit of the range. They rise to uniform elevations, the isolated peaks are generally flat-topped, and their ridges have likewise approximately level summits.

Beginning at the north, the first elevations of this kind are found in the Grizzly Mountains, in the northern part of the Downieville quadrangle; their level summits, consisting of old greenstone and Carboniferous slates, are conspicuous. A few miles farther south begins another prominent ridge which culminates, with an elevation of 8,615 feet, in the Sierra Buttes. All these eminences are distinctly within the upper drainage of the present Feather and Yuba rivers.

In the Colfax quadrangle we have Pinoli Peak, English Mountain, Grouse Ridge, and Signal Peak, all from 7,500 to 8,000 feet in elevation. In the Truckee quadrangle the old ridge is represented by Snow Mountain and McKinstry Peak, and we here approach the main divide of the range, which, however, is marked rather by high ridges of andesite representing dissected Tertiary volcanoes than by high eminences of the older rocks. In the Pyramid Peak quadrangle, in the direct southward extension of the high region, lies the Pyramid Peak Range, which in effect is a long ridge of granite rising steeply to elevations of 9,000 and 10,000 feet above a granitic plateau. To the east of the Pyramid Peak Range are, however, a number of points of similar elevations; most conspicuous among them and overlooking Lake Tahoe stand Mount Tallac and the adjoining ridges.

South of the South Fork of American River high ridges continue to Mokelumne Peak, but south of this point it is doubtful whether the old divide can be followed.

We have then here, extending for 100 miles, an old and greatly eroded summit line which does not coincide with the present divide of the range. Neither does it entirely coincide with the Tertiary divide of Eocene or Miocene time. It is true that at the north this ridge divided the drainage basin of the westward-flowing Yuba River from that of the northward-flowing Jura River; but in the vicinity of the Central Pacific Railroad we find that a branch of the Yuba River cut through this old ridge southeast of Snow Mountain and headed several miles to the east of that ancient summit line. (See Pl. I, in pocket.) Similar conditions prevailed in the Pyramid Peak quadrangle, where the main fork of the Tertiary American River broke through

the Pyramid Peak Range in a deep canyon. Its headwaters extended much farther east and are probably to be found at some place in Alpine County, in the Markleeville quadrangle.

To the west of this old divide a number of flat-topped mountains rise to elevations of about 6,000 feet; prominent among these are Robbs Peak, in Eldorado County; Canada Hill, Bald Mountain, or Duncan Peak, in Placer County; and several others. Most of these peaks consist of harder masses of metamorphic slate which have resisted erosion better than the granodiorite.

All these level-topped peaks and ridges, rising prominently above the general surface of Tertiary time, undoubtedly indicate a far older eroded surface, uplifted and dissected long before the auriferous gravels were deposited or the lava flows extruded.

The important fact that the Tertiary rivers cut back behind this pre-Tertiary divide and robbed the streams to the east of it indicates that the eastern slope at one time had a slighter grade than the western; in other words, the western streams were superior in eroding power.

The exact age of this ancient topographic surface is difficult to ascertain. It assuredly antedated the Eocene and it may be early Cretaceous. The line of high peaks indicated above is believed to represent the crest line of the Sierra Nevada in Cretaceous time. (See Pl. XVIII, p. 134.)

EASTERN FAULT SYSTEM.

OUTLINE OF SYSTEM.

The great fault which delimits the Sierra Nevada from the Great Basin on the east has attracted the attention of every geologist who has studied the range. It finds expression in an imposing scarp which can be followed from a point about 40 miles south of Owens Lake, in latitude 35° 30′, to Honey Lake, in latitude 40° 20′, a total distance of 350 miles. (See fig. 3.) When studied in detail it proves to be a complicated fault system produced by a number of successive movements.

The south end of the fault line bends sharply to the west and gradually loses itself toward Tehachapi Pass. North of Honey Lake the fault is covered by heavy masses of Quaternary lava. The fault scarp is most imposing south of Owens Lake, where it descends abruptly from elevations of 11,000 feet to 3,569 feet. From Owens Lake the fault scarp can be followed almost continuously to Mono Lake, which also lies at its immediate foot. From Mono Lake northward instead of a single fault there is a system of dislocations, spreading out northward, each dislocation being usually offset from the next by a few miles, en échelon. The main fault continues only for about 50 miles northwest of Mono Lake and is still apparent by its steep escarpment on the west side of West Walker River near the California-Nevada boundary line. About 10 miles to the north of Markleeville begins another fault line which extends northward in Nevada to a point a few miles south of Reno. Another offset of a few miles probably exists here, although the covering Tertiary andesites veil much of the structure. From a point about 10 miles west of Reno, near the State line, an escarpment indicating a fault extends at first in a northerly direction, but with some irregularities which indicate the existence of several parallel faults. From Long Valley to a point near Susanville the extremely well marked fault scarp runs in a northwesterly direction but within a short distance diminishes in height and becomes covered by lavas.

From Lake Tahoe northward a series of gradually diverging faults extend toward Plumas County. The first is indicated by the eastern shore of Lake Tahoe but dies out a short distance south of the Lake. To the north it continues with a slight offset at the north end of the lake and forms a westward-facing escarpment extending in all 70 miles northward to the east side of Sierra Valley. A similar fault, but with a scarp facing eastward, begins a few miles south of Lake Tahoe and continues northward along the west side of the lake though locally obscured by heavy masses of andesites. This fault line skirts the southwest side of Sierra Valley and here bends more sharply to the northwest. It has been identified along the west side of Mohawk Valley and is probably continued to the northwest as far as Quincy. A third fault line, not so conspicuous as the one just mentioned, lies about 18 miles to the southwest of Mohawk Valley; it begins near La Porte and continues for 20 miles to the northwest. An intermediate disturbance

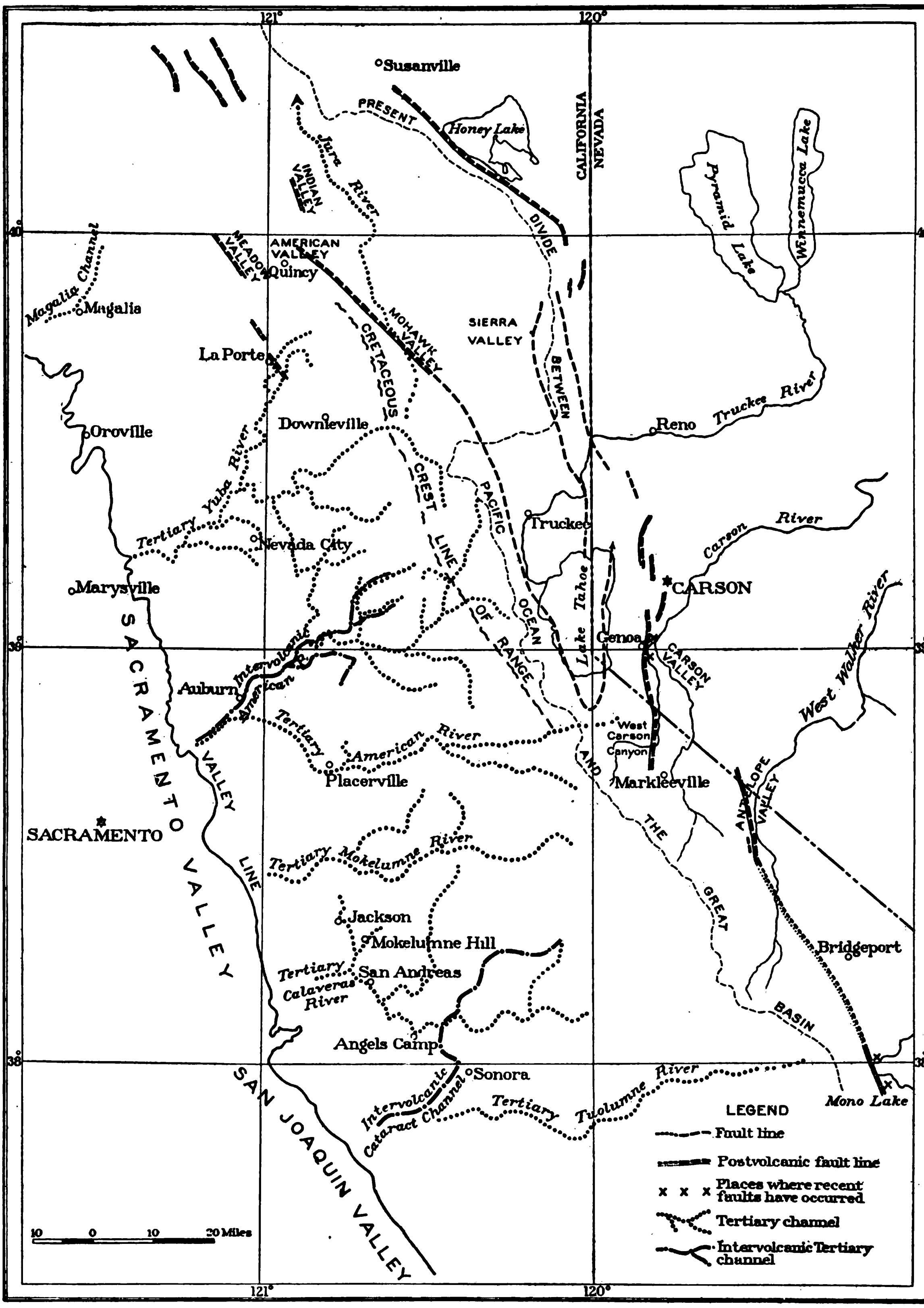


FIGURE 3.—Outline of Tertiary channels and of dislocations along the eastern base of the Sierra Nevada.

appears between the two lines and fault scarps belonging to it may be observed in the vicinity of Meadow Valley. In this northern part of the Sierra appears a feature which is not noted in the southern part of the range; that is, a number of local depressions along fault lines, forming small closed valleys. The most prominent among these are Meadow Valley, Indian Valley and American Valley, all in Plumas County.

In the great lava fields of the Lassen Peak region, north of the last exposures of the "Bed-rock series" along the North Fork of Feather River, J. S. Diller has noted a number of short fault lines in the general extension of those of the Sierra Nevada, but they can not be traced far nor are the dislocations along them considerable.

The whole system of fault lines, as briefly described above, is outlined on Plate I (in pocket). Along the main eastern line the height of the scarp gradually decreases toward the north. From heights of 5,000 to 6,000 feet the scarps are reduced to declivities of about 2,000 feet at Honey Lake. Similarly, the dislocations diminish in throw toward the west and along the last fault line at La Porte the dislocation is only about 200 feet.

CHARACTER OF DISLOCATIONS.

In a number of places where comparatively recent displacements have occurred it is possible to ascertain the character and the direction of the movement. A noteworthy feature is that the bottom of the fault scarp is closely hugged by the depressions. The waves of Mono Lake break against the foot of the escarpment. In Antelope Valley, West Walker River runs at its foot and no débris fans from the ravines in the escarpment are visible. Exactly the same may be said of the imposing escarpment at Genoa, south of Carson, where the marshes of Carson River mark the foot of the steep face of the slope and at Franktown, where the Washoe Valley lies in a similar position. At Honey Lake the same conditions are repeated.

All this shows clearly that the dislocation along this line consists in a sinking of the eastern blocks. Nowhere can any evidence be found substantiating the theory that the fault scarp has been formed by an uplift of the western block.

In many publications the greatly increased grade of the Tertiary rivers and of the surface of the range as a whole is ascribed to an uplift of the range along the eastern break, accompanied by a tilting of this lifted block. An inspection of the profiles across the range shown in Plate IX (in pocket), will easily convince the observer that such an explanation is wholly untenable. East of Lake Tahoe the total displacement by the faulting which occurred in late Tertiary time just before the andesitic eruptions amounted to only 2,200 feet. Such an uplift would be utterly insufficient to change the grade of the western Tertiary rivers from say 20 feet to the mile to 90 or 100 feet to the mile. All this strengthens the belief that we have here to deal with a composite movement, the upward element affecting a large area and the downward element consisting in the local sinking of moats (graben).

TIME OF MOVEMENT.

The main break along the east side of the range is one of great antiquity, probably dating back at least to the last part of the Cretaceous, but movements have recurred at different times and the fault system became greatly extended by additional breaks at the close of the Tertiary. Post-Tertiary and recent movements have taken place in many localities.

The testimony furnished by the Tertiary rivers on the western slope indicates unmistakably that a tilting movement took place during the andesitic eruptions in late Tertiary time, shortly after the close of the rhyolitic eruptions. Approximately corresponding to this movement in time was extensive faulting and displacement along the eastern border, and it was held for many years that the entire eastern scarp was then formed. More detailed investigations have disproved these views and have shown that at the time of the deposition of the auriferous gravels, before the volcanic eruptions, the present fault lines were in the main established. The relations of the contact lines between the andesites and the underlying rocks show that the scarp extending along the west side of Lake Tahoe existed before the volcanic eruption. This testimony

is corroborated by a study of the channels, which can be traced back to their headwaters along a divide overlooking the lake that practically coincides with the present summit of the range. The same is true of the fault line on the east side of the lake, and there is a very strong probability that the principal fault line, facing the Great Basin, was also defined before the Tertiary period. Before the eruption of the great masses of andesites in the Truckee Valley and the accumulation of Quaternary and Tertiary detritus in Sierra Valley the two depressions formed a continuous "graben" between two fault scarps and probably drained northward.

The mountain-building movements were, as stated above, resumed on a great scale at the close of the Tertiary. The andesitic flows furnish the best means to determine the date of these movements.

The most easterly fault line appears in the area described in this volume only in the southeast corner, at Antelope Valley. The evidence presented in the chapter on the Markleeville quadrangle indicates that the postandesitic faulting at this place amounted to only 500 feet—that is to say, the bottom of the Antelope Valley is held to have dropped 500 feet shortly after the andesitic eruptions.

The next fault line, extending from a point northeast of Markleeville nearly to Reno, indicates a postandesitic faulting of 2,000 feet. The detailed evidence for this conclusion is presented in the chapter on the Carson quadrangle and is derived both from direct evidence along the fault scarp and from the peculiar behavior of the upper canyon of Carson River where it breaks through this fault. Here again the dislocation is considered to consist in a depression of the Carson Valley of about 2,000 feet.

Along the eastward-facing fault scarp west of Reno the evidence of postandesitic faulting is not convincing and apparently this scarp was already in existence before the andesitic flows were poured over its flanks. So far as the examinations have been concluded, no postvolcanic dislocation took place along this scarp as far north as Sierra Valley, but from that vicinity nearly to Susanville the recency of the movement is very striking. As has been shown by J. S. Diller, the whole of the displacement at Honey Lake is decidedly later than the andesitic flows. Volcanic hills, probably old craters, on the summit of the ridge have been cut in two and the entire amount of the subsidence, probably about 2,000 feet, must have taken place comparatively recently, perhaps at the beginning of the Quaternary and assuredly later than the dislocation south of Reno.

There is little evidence of postandesitic faulting along the whole course of the dislocation with westward-facing scarp overlooking Lake Tahoe and continuing northward to Sierra Valley. The same may be said of the fault line west of Lake Tahoe, at least as far north as Sierra Valley, but from that locality on conditions changed and a postandesitic fault, marked by an eastward-facing scarp, has been clearly demonstrated by H. W. Turner along the Mohawk Valley, the downthrow on the east side amounting to 2,000 or 3,000 feet. The time of this dislocation can be indicated with more exactness, for on one hand the fault cuts Neocene gravels and rhyolite high up on the scarp, and on the other hand the deep depression was occupied in late Tertiary time by a lake which contains beds of andesitic tuff. The dislocation therefore dates from intervolcanic, late Tertiary time.

Of the same age as the Mohawk Valley fault are those at American Valley and Meadow Valley, for in both places the andesitic flows and the gravels have been cut by the dislocations.

A particularly interesting fault is the one extending from La Porte northwestward. A Neocene river, described in the chapter on the Downieville quadrangle, crosses this break and the study of its grade allows definite conclusions as to the mechanics of the disturbance. The fault zone comprises at least three dislocations within a distance of a mile, having a total downthrow on the northeast side of 500 feet. (See fig. 8, p. 108.) For 8 or 9 miles east of the fault zone the grade of the Tertiary river has been increased to 200 feet to the mile. The normal grade is 100 feet to the mile, but this represents a great increase over the original slope of the river bed before the uplift of the Sierra Nevada. We have here, then, evidence of two movements—the general uplift, increasing the grades to 100 feet to the mile, and a second movement, consisting in a drop on the east side of a fault zone, resulting in a stronger westward tilt of the

subsided block. The first movement is supposed to have taken place at the end of the Tertiary and it is probable that the second movement followed the first rather closely.

On a much larger scale a similar condition of affairs is found south of Carson, Nev., where there was a postvolcanic fault of 2,000 feet throw. The long westward slope of the foothills of the Pine Nut Mountains is formed by gently westward-sloping lake beds, in the same position relative to the fault as the tilted block at La Porte.

To sum up, faulting has recurred irregularly along the eastern fault zone since the Cretaceous period. The subsidences along the faults are not uniform. A Cretaceous dislocation along one line may be continued by a late Tertiary fault on the extension of this line. These relations are indicated in figure 3 (p. 40) and Plate I (in pocket) in a general way. It follows from the irregularity of the subsidence which has taken place at different times that these movements can in no way have been responsible for the uniform tilting of the western slope.

CRITERIA OF FAULTING.

In some places—for instance, along the west side of Lake Tahoe—the only evidence of faulting consists in the sharply descending slope. Along the fault to the east of Lake Tahoe the scarp itself cuts an old, probably Cretaceous, surface and the relations are so clear that no one can for a moment doubt that an actual dislocation has taken place. Along the principal eastern scarp—for example, at Genoa— the contrast between the abrupt slope and the marshes extending at its foot is so great as to indicate that no erosion could have performed this work. Moreover, one of the characteristics of fault planes is here very marked—that is, a slope gradually becoming steeper as the foot of the escarpment is approached. At other places the dislocation of the channels and the overlying lavas give, of course, unmistakable and positive evidence of the faulting.

THE QUATERNARY DRAINAGE.

The development of the Quaternary drainage system of the Sierra Nevada is a subject outside the scope of this report. It is in fact a most interesting study, full of complications, and its careful examination should lead to valuable physiographic results.

At the close of the andesitic epoch the northern Sierra Nevada was covered to a great extent by an undulating sheet of tuffs and breccias. The main mass of this embraced Nevada, Sierra, Placer, Eldorado, Calaveras, and Amador counties. Even here there rose above the sloping plain numerous peaks and ridges, somewhat like the nunataks of Greenland, projecting above the ice sheet. In Yuba and Butte counties large areas were never covered by andesitic flows and south of Calaveras County the conditions were similar.

Over the sloping andesite table the Quaternary streams were laid out as consequent watercourses, dependent on the small inequalities of the lava flow for details but assuming a general direction toward the west-southwest, or in the direction of the greatest declivity of the range. Even here, however, the ancient watersheds were, in a measure, preserved, owing to the guiding influence of the dividing ridges.

Yuba River plainly followed, in its lower course, the general direction of the Tertiary stream. South of Calaveras County, where few andesitic flows existed, the Quaternary rivers followed the Tertiary valleys, simply deepening their channels. Upper Tuolumne River is a good example of this tendency. In these areas the normal development of the Tertiary streams comprised a master stream perpendicular to the direction of the range and numerous tributaries, the courses of which were largely determined by the hardness of the various belts of rocks attacked by erosion.

A great number of valleys, generally occupying granitic areas and surrounded by ridges of more resistant rocks, are found on the middle and lower slopes of the range. As instances may be taken the lower Deer Creek Valley and Penn Valley, in Nevada County. On a larger scale this is also exemplified in the Ophir Valley, west of Auburn, in Placer County. Although these valleys are now deepened below the level of the Tertiary surface, it is clear that they were

in the first place determined by the inequalities resulting through long and slow denudation during the Tertiary period.

In the high Sierra, especially from southern Placer County southward, the Tertiary lava flows have had comparatively little influence and the present drainage is simply the result, with some modifications, of a deepening of the Tertiary watercourses. The Rubicon Valley, for instance, west of Lake Tahoe, was clearly outlined before the Tertiary period and in its present form has been further modified by Quaternary erosion and glaciation.

On the eastern slope of the range the influence of late Tertiary dislocations is strongly felt. This appears most strikingly in the various parts of Carson and West Walker rivers, which in their upper courses more or less closely follow the sunken area between the fault blocks.

The origin of Truckee River is not fully explained, but it seems probable that it was forced to break across the volcanic range east of Truckee as a consequence of an overflow from the late Tertiary Truckee Lake. It also seems probable that it is antecedent in a way, because some slight uplift has probably occurred along the margin of that range since the drainage lines were established.

SUMMARY OF THE HISTORY OF THE RANGE.

The major features of the beginning of the Cretaceous history of the Sierra consisted in the plication and welding of the Mariposa formation with the older sediments and active eruptions, continued from the Jurassic period, among the lofty volcanoes along the foothills, which were washed by the sea, and finally the intrusion, in the foundations of the range of enormous batholiths of dioritic and granitic magma. A mountain range of great height must have occupied the site of the present Sierra Nevada. Long-continued erosion planed down this range to a surface of comparatively gentle topography. Of this old Cretaceous topography traces still remain in a number of flat-topped hills and ridges that rise high above the later Tertiary surface. There is reason to believe that this planed-down mountain range had a symmetrical structure, for somewhat to the east of the present divide is a well-marked old crest line extending from the Grizzly Mountains on the north, in Plumas County, at least as far south as Pyramid Peak, in Eldorado County. At some time in the later part of the Cretaceous period the first breaks took place, changing the structure of the range from symmetrical to monoclinal and outlining the present form of the Sierra Nevada.

Even at this date the orogenic disturbance was probably of a twofold character, consisting of the lifting up of a large area including at least a part of the present Great Basin, and a simultaneous breaking and settling of the higher portions of the arch. Along the eastern margin a system of fractures was thus outlined which toward the close of the Tertiary was to be still further emphasized. The main break probably extended from a point south of Mono Lake to Antelope Valley and from Markleeville northward toward Sierra Valley. A large part of the crust block to the west of this dislocation also sank down. This sunken area is now indicated by Lake Tahoe and by its northward continuation, Sierra Valley, separated from each other only by masses of Tertiary lavas. There is no indication that the fault lines of Honey Lake and the Mohawk Valley existed at this time. It is also worthy of note that within the area of the range no volcanic eruptions accompanied this subsidence.

As a consequence of this uplift the erosive power of the streams was rejuvenated, the Cretaceous surface of gentle outline was dissected, and the rivers began to cut back behind the old divide, carrying their heads nearly to the present crest line that separates the slope of the Sierra from the depression of Lake Tahoe. This erosion was continued for a long time and resulted in the development of broad U-shaped valleys, which toward the crest of the range became deeper and narrower, and which along the valley border found their outlets across the greenstone ridges in valleys that also were narrow compared to the more open country along the present middle slopes.

What the grades then were is, of course, impossible to determine with absolute accuracy. The Tertiary rivers running parallel to the range, a position most favorable for low grades, have channels which are now inclined from only a few feet up to 20 feet to the mile. It may be

assumed, then, that in the lower reaches of the main channels the grades rarely exceeded 30 feet to the mile and probably averaged considerably less. At the same time the coarseness of the deep gravels and the deep narrows that occur here and there clearly point to streams of considerable power of transportation. (See description of Polar Star mine and Big Dipper mine, Colfax quadrangle, pp. 144 and 149, also Pl. XXI, *B*, p. 144.) Much has been written to explain the causes leading to the deposition of the heavy bodies of Tertiary gravels after the epoch of erosion had been concluded. Whitney assumed that the grade had not changed and sought the explanation of the heavy gravel masses in increased precipitation and generally changed climatic conditions. Diller[1] held that at the close of the Eocene epoch disintegration exceeded transportation and that consequently the surface was covered with a deep mantle of decomposed material, which was rapidly swept into the river courses owing to a slight uplift that increased the erosive power of the streams. Undoubtedly the accumulation of rich gold-bearing gravel implies a previous long-continued decay of the rocks, and under the conditions of gentle grade and topographic maturity which characterized the late Cretaceous and the earliest Tertiary in the Sierra Nevada such decay must have been going on. On the other hand, it is to be remembered that the great richness of the gravels and the worn condition of the gold and pebbles imply a long period of accumulation under well-balanced conditions so that a certain moderate depth of gravel was maintained for a long time. Under such conditions the concentration of the gold would be greatly facilitated both by sinking of the particles through the gravel and by a continuous though slow downstream movement of the detritus in the rivers. In this connection it is worthy of note that the lower narrow valleys through the greenstone ridges must have acted as barriers tending to hold the gravels in the middle reaches of the streams. Along the Tertiary Yuba River, where these conditions were emphasized, we find both the richest and the deepest gravels. In the rivers which flowed into the gulf farther south the early gravels are thin and in some places absent, for in these channels there was less damming in the lower courses.

The subsequent heavier accumulation of finer and more quartzose bench gravels was undoubtedly caused by the Ione transgression of the waters of the gulf to present elevations of about 800 or 1,000 feet. The recession of the waters was followed by a short epoch of erosion before the beginning of the rhyolitic flows. Here again the great channel system of the Tertiary Yuba River is particularly distinguished by the heavy accumulation of finer-grained quartz gravels, but in the rivers to the south no heavy masses of gravel really began to be stored until the beginning of the rhyolitic eruptions, which, of course, had the effect of retarding the erosive power of the streams. In this case also, then, the accumulation of the gravels is rather a consequence of special conditions than of general climatic or orogenic causes.

After the channels had been filled to a considerable depth the concentration of gold practically ceased. It must be remembered that under ordinary conditions it is not possible for grains of gold of even moderate coarseness to be carried out into the middle of broad flood plains. It is assumed by many that the present concentration of gold on the bedrock is due to a gradual sinking of particles formerly distributed throughout the thick gravels, but this view is probably wholly incorrect.

The epoch of rhyolite eruption closed and was succeeded by that of the andesite. Shortly after the beginning of the andesitic eruptions there occurred a most striking phenomenon—a sudden increase in erosive power. The streams in the broad flood plains began to cut sharp V-shaped canyons, eroding and locally concentrating the old gravels. Although this erosion was suddenly stopped by the overwhelming floods of andesitic tuffs and breccias, yet it marks unmistakably the beginning of the orogenic disturbances which sharply increased the grade of the western slope. Faulting was renewed along the eastern margin, following the old lines or breaking new ones. Along the principal eastern scarp, from Owens Lake to Antelope Valley, the displacement was probably very large at some points, but at the north end at Antelope Valley the measured throw is only about 500 feet. Along the escarpment extending from

[1] Diller, J. S., Tertiary revolution in the topography of the Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 427.

Genoa to Reno the displacement, consisting in a sinking of the eastern block, was about 2,000 feet. On both sides of Lake Tahoe little or no movement seems to have taken place, but new faults were opened in Mohawk Valley and along several lines to the west of it. Still later, probably, is the fault extending from Sierra Valley to Susanville and here the downthrow on the east side was 2,000 feet.

In Plate IX (in pocket) two sections (*A–B* and *C–D*) are laid down across the range and drawn on the same vertical and horizontal scale. They indicate clearly the absolute insufficiency of the eastern faults to account for the increase in slope demonstrated by the grades of the channels, and they also bring clearly to mind the remarkable rigidity of the western block, in which, aside from a uniform westward tilt, the deformation has been extremely small. It would be an interesting problem to calculate the depth that this block must have had in order to act as a rigid body during this tilting over a distance from north to south of several hundred miles and from east to west of about 80 miles. In the northerly section the Tertiary river courses have, it is true, been traced back only to the Cretaceous divide indicated by English Mountain; but in the southerly section the old channel of American River practically reached a point south of Lake Tahoe and probably even somewhat east of it, while the channel of the Tertiary Tuolumne River is traceable almost up to Mount Dana.

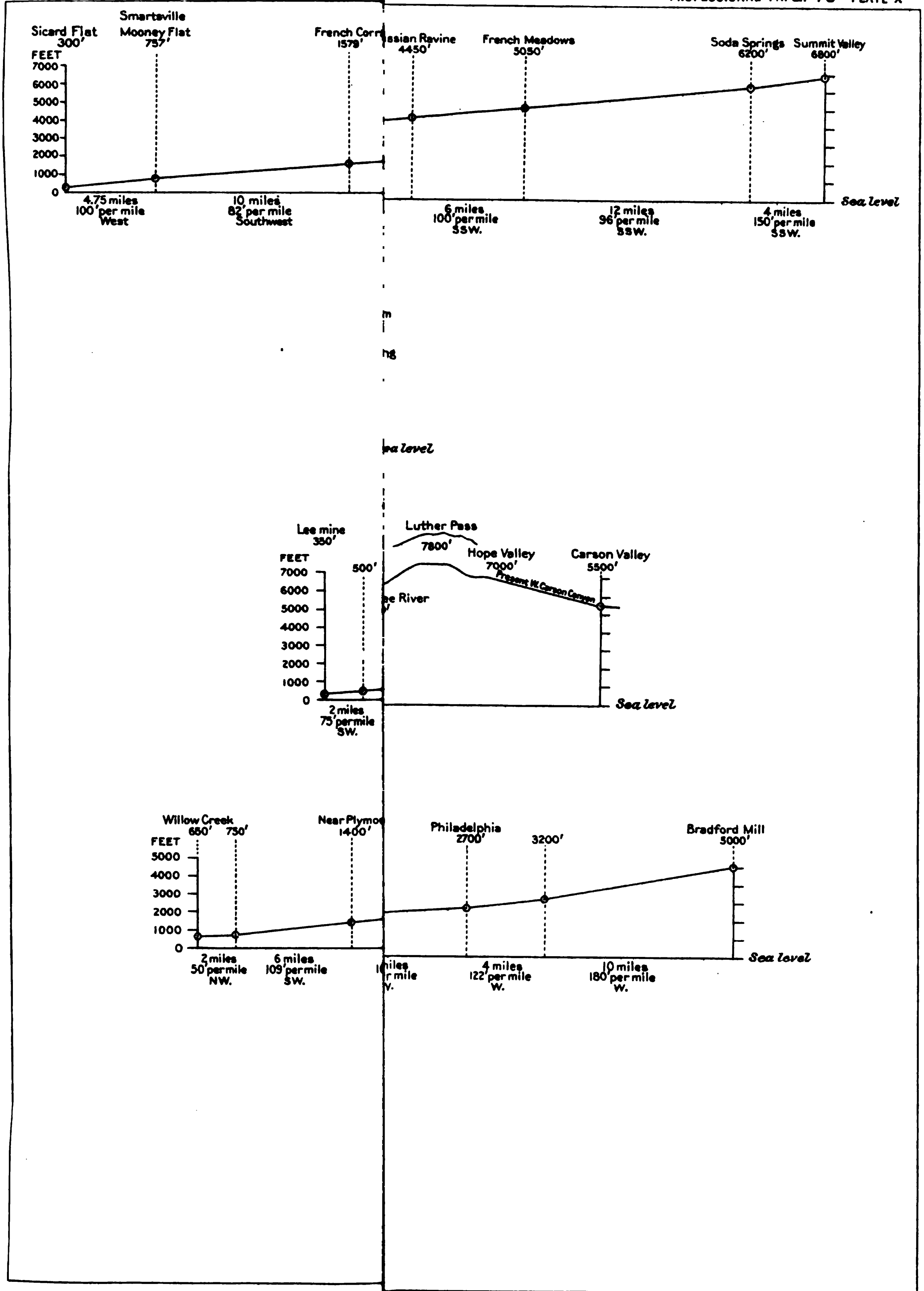
G. F. Becker considered that the explanation of this tilting movement of a solid block met many difficulties, and he advanced the theory[1] that the range was intersected by a system of northwestward-trending joint planes on which had taken place small movements that would aggregate large amounts and account for the tilting movement. (See Pl. VII, *B*, p. 32.) Such joints are indeed found in several places along the summit region and not far from fault planes or extensions of fault planes, but no evidence of their existence can be gathered from the lower slopes. Moreover, it seems to the writer an impossibility that so extensive a system of distributed faults in heterogeneous rocks could have been produced without strongly deforming the Tertiary river grades over a distance of 60 or 70 miles. The results presented here are believed to establish firmly the fact of an uplift and tilting of a large block of the earth's crust, including the Sierra Nevada, a part of the Great Basin, and the region underlying the Sacramento Valley along its east side.

The view to which these studies have led comprises, then, a great epeirogenetic and remarkably uniform uplift of a large part of the continent, perhaps accompanied by a sinking or flexure along the continental margin, and further a local and irregular breaking down and settling of parts of the lifted block.

In recent time movements have been renewed along the main fault scarp at Owens Lake, at Mono Lake, and at Genoa, Nev., but it is thought that these recent displacements are relatively small. That near Genoa amounts to about 50 feet. The movements along the fault line were probably paroxysmal rather than spread out over a large interval of time. The lake in the Mohawk Valley depression, for instance, was plainly formed a very short time after the downward movement along this block began. Similarly, the existence of the narrow and deep canyons of Truckee and Carson rivers through the Virginia Range in Nevada affords good evidence that the subsidence of the block immediately east of the main fault scarp of the Sierra was completed within a relatively short time.

On Plate X a number of profiles showing the present grades of the Tertiary rivers have been plotted, each profile showing the distance between established points along the river channel, its direction within this interval, and the grade in feet to the mile. In examining these sections it should be remembered that the axis of the range has a north-northwesterly direction. On the assumption that the range as a whole has been tilted, any part of the Tertiary river flowing in a west-southwest direction would have its grade increased to a maximum amount, and any channels extending north-northwest or south-southwest would show little if any change in grade. The influence of the tilting would gradually decrease as the direction of the channel swung around from west-southwest to north-northwest or south-southeast.

[1] Bull. Geol. Soc. America, vol. 2, 1891, pp. 49–74.


Sicard Flat 300'
Smartsville Mooney Flat 757'
French Corr 1579'
ssian Ravine 4450'
French Meadows 5050'
Soda Springs 6200'
Summit Valley 6800'
FEET
7000
6000
5000
4000
3000
2000
1000
0
4.75 miles 100' per mile West
10 miles 82' per mile Southwest
6 miles 100' per mile SSW.
12 miles 96' per mile SSW.
4 miles 150' per mile SSW.
Sea level
m
ng
ea level
Lee mine 350'
500'
e River
Luther Pass 7800'
Hope Valley 7000'
Carson Valley 5500'
Present Mt Carson Canyon
FEET
7000
6000
5000
4000
3000
2000
1000
0
2 miles 75' per mile SW.
Sea level
Willow Creek 650' 750'
Near Plymo 1400'
Philadelphia 2700'
3200'
Bradford Mill 5000'
FEET
5000
4000
3000
2000
1000
0
2 miles 50' per mile NW.
6 miles 109' per mile SW.
iles r mile
4 miles 122' per mile W.
10 miles 180' per mile W.
Sea level

On the other hand, a river flowing in an east-northeast direction would be so affected by the tilting as to show a diminution or a reversal of grade, and this influence would gradually lessen as the direction swung around from east-northeast to lines parallel to the direction of the range.

The profile of the main fork of the Tertiary Yuba River (Pl. X) is particularly instructive. In its lower part, where the river broke across the greenstone ridges of the foothills, the direction is west to southwest and the grades from 65 to 100 feet to the mile, the heaviest grade being recorded in the lowest portion, strongly suggesting a slight deformation near the deep trough of the Sacramento Valley. The stretch extending from Badger Hill to Forest Hill shows, as a rule, slight grades corresponding to a north-northwesterly direction; here and there the grades are reversed owing to a local easterly direction. Above Forest Hill the southwesterly directions are resumed with some local exception and the grades range from 75 to 100 feet to the mile, increasing immediately at the headwaters to 150 feet. It is altogether unlikely that the original grades in the upper part of the river were the same as those near its mouth, and this increases the probability of the conclusion that the deformation was slightly more marked near the valley.

The second profile on Plate X shows the grades of the North Fork of the Tertiary Yuba River. The grades are steep throughout and the directions in general southwesterly. Near the headwaters some faulting is noted, accompanied by an increase of grades to wholly abnormal figures—about 200 feet to the mile. At Gibsonville the channel is broad and filled with well-washed gravel; apparently its headwaters are a considerable distance to the northeast, but the channel can not be traced farther than Hepsidam.

In the third profile on Plate X are given the grades of the Tertiary and present American River. The Tertiary stream can be traced to the very crest of the range at Lake Audrain and it probably continued across the Little Truckee through the remarkable wind gap of Luther Pass, overlooking Hope Valley in Alpine County. This trench of the Little Truckee was probably cut at some time in the early Tertiary. The direction of the Tertiary river, except in the short distance from Granite Hill to Diamond Spring, was westerly or west-southwesterly. The grades are strong throughout, being about 75 feet to the mile near the valley and increasing beyond the vicinity of Placerville from 75 to 177 feet to the mile. The increase in grade from mouth to source seems perfectly normal and we are forced to conclude that aside from the uniform tilting of the range there has been little deformation of this channel. The approximate height of the bedrock hills rising above the Tertiary channel is indicated. The profile also shows the present grade of the South Fork of American River, which closely follows the direction of its Tertiary ancestor. It has the well-known combination of two concave curves, the more easterly, near the headwaters, resulting from the influence of glaciation on an earlier, uniformly eroded canyon.

The next profile on Plate X shows a part of the Tertiary Mokelumne River, a comparatively short stream. Here again the influence of direction on grade is clearly perceived, especially in the lower and upper parts of the course. Where the direction is southwest or west-southwest the grade ranges from 100 to 133 feet to the mile.

The Tertiary Calaveras River is known only in the lower half of its course. From Central Hill to Angels the general direction is northwest and grades up to 30 feet to the mile prevail; these are probably only slightly greater than the original declivity. Beyond Angels the general direction is west or southwest and the grade increases rather regularly from 75 to 180 feet to the mile. Here, too, we are forced to the conclusion that practically no deformation beyond the uniform tilting of the range has taken place.

Plate X gives also the profiles of the Tertiary and present Tuolumne River, both following closely the same course. In its lower part we find grades of 90 feet to the mile, with a westerly direction. In the middle course the grade decreases to 57 feet to the mile, in accordance with a swing to the west-northwest. The data for the stream above the eastern boundary of the Sonora quadrangle are not complete, but it is certain that the Tertiary channel extended as far as

Piute Creek and it probably headed near Mount Dana. In this upper course the grades are about 130 feet to the mile. In the profile of the present river we note the same combination of two concave curves, the influence of glaciation being felt as far as Hetch Hetchy Valley.

The last four profiles, of the southern rivers, are thoroughly consistent and indicate uniform tilting of well-graded rivers without perceptible deformation.

VIEWS OF KING, LE CONTE, AND RUSSELL.

It is interesting to note that three eminent geologists—King, Le Conte, and Russell—who well knew the Sierra Nevada and the Great Basin, arrived at the same conclusion—that the uplift involved both regions and that the faults were accompanied by downthrows on the east side.

King,[1] after discussing the folding and subsequent faulting of the Great Basin, says:

> The result of this complicated interlacing system of dislocation is that all ranges of the Great Basin have been broken into irregular blocks, sections of which have sunk many thousand feet below the level of the adjoining members. * * * The two grandest fault lines shown in the Great Basin are those which define its east and west walls. Whoever has followed the eastern slope of the Sierra from the region of Honey Lake to Owens Valley can not have failed to observe with wonder the 300 miles of abrupt wall which the Sierra Nevada turns to the east. That wall is no other but a great continuous fault by which the Nevada country has been dropped from 3,000 to 10,000 feet downward. In this low trough, east of the Sierra Nevada and Cascade Range, is laid down the thick series (amounting to 4,000 feet as already described) of Miocene beds. It is therefore evident that this was a depression which was defined before the beginning of Miocene times. * * * As yet in the depressed area east of the Sierra Nevada no Eocene beds have been discovered, from which it seems highly probable that the great fault occurred either within the Eocene or at the close of Eocene time and was the direct cause of the subsidence whose area was immediately occupied by the Miocene Pahute Lake.

These views are similar to those expressed later by Le Conte[2] in a paper on the origin of normal faults. He writes:

> The whole region from the Wasatch to the Sierra, inclusive, was lifted by intumescent lava into a great arch, the abutments of which were the Sierra on the one side and the Wasatch on the other. * * * The arch broke down and the broken parts readjusted themselves by gravity into the ridges and valleys of the basin region, leaving the abutments overlooking the basin and toward one another.

Russell[3] was the first to recognize the compound character of the great fault system. He says:

> On the west side of the Great Basin, at the immediate base of the Sierra Nevada, there is an immense compound displacement that can be followed all the way from Honey Lake on the north to beyond Owens Lake on the south, a distance of over 350 miles. Among many of the faults composing this belt the records of a post-Quaternary movement may be clearly recognized. Fault scarps produced by the recent movements have been observed in Eagle and Carson valleys, south of Carson City, in Bridgeport Valley, and on the west side of Mono Lake. The earthquake in Owens Valley in 1872 was caused by a movement along one of the faults of this series.

In a later paper[4] Russell describes a recent scarp at Mono Lake and makes some pertinent observations as to the character of the dislocation, substantially as follows:

> A fault scarp having a throw of 50 feet crosses the moraines and the delta deposits at the mouth of Lundy Canyon. The beach lines are deformed. The difference in elevation of the beach line on opposite sides of the displacement, as indicated by the measurements, is less than the height of the recent fault scarp and shows that the greatest movement has been in close proximity to the line of faulting.
>
> The simplest hypothesis which seems to explain the facts observed is that a recent movement has taken place along the fault which has resulted in a displacement of at least 50 feet. That the displacement was caused or at least accompanied by a subsidence of the block forming the thrown side of the fault is indicated by the present position of Lake Mono. Assuming that the basin had been undisturbed since its occupation by the ancient lake, it is evident that sedimentation would have been greatest along the southwestern border, where the creeks from the mountains empty into it, and that this portion of the depression would have been filled much more rapidly than the northern border, where there are no tributaries. The present lake, under these conditions, should have been somewhat removed from the mountains, as it would have been crowded northward by progressive sedimentation. We find, on the con-

[1] King, Clarence, U. S. Geol. Expl. 40th Par., vol. 1, Systematic geology, 1878, pp. 742–744.
[2] Le Conte, Joseph, Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 262.
[3] Russell, I. C., Notes on the faults of the Great Basin and of the eastern base of the Sierra Nevada: Bull. Philos. Soc. Washington, vol. 9, 1887, pp. 5–7.
[4] Quaternary history of Mono County, California: Eighth Ann. Rept. U. S. Geol. Survey, pt. 1, 1889, pp. 302–304.

trary, that it washes the very base of the mountains and occupies the position that would result from orographic movement of the nature indicated by the deformation of the beach lines. The eccentric position of Lake Mono in reference to what would be its normal position had the basin remained undisturbed is in all respects similar to the abnormal position of Great Salt Lake and is due to a similar tilting of its basin.

The shifting of the load from the mountains to the valley would tend to produce such a movement as has been observed; it may be in part the cause of the recent movement, but the commencement of the faulting must have occurred before any considerable transfer of load could have taken place and is probably due to other causes.

The variations of surface temperatures, weight of water in ancient lake basins, transfer of load from the heaved to the thrown side of a fault, etc., by which the movements have been explained by various writers, it seems to me are secondary results of some great slow-working and wide-reaching series of forces which have made themselves felt * * * throughout the Great Basin.

SEDIMENTATION AND EROSION.

To those who study the larger movements of the earth's crust and their relation to sedimentation and erosion the Sierra Nevada presents a particularly important problem. A mountain range since earliest Cretaceous time, subject continuously to erosion and intermittently to orogenic movements, it faced the western sea for a long period during the Cretaceous and early Tertiary and its streams discharged into this sea enormous masses of sediments.

The problem, in so far as it relates to subsidence of the Great Valley caused by the weight of the sediments from the erosion of the Sierra, has been effectively treated by Ransome.[1]

Some students of the geology of the Pacific slope, particularly G. F. Becker,[2] have thought that the uplift of the Sierra Nevada is due to the isostatic subsidence of the sediment-laden valley floor, which would produce a viscous flow of material underneath the rising mountain mass. Ransome rejects this explanation, showing by a diagram the decided incompetency of the sedimentary mass of the valley, even if liberally measured, to produce an elevation of the range. According to the results presented in the present report the incompetency is even greater than was indicated by Ransome, because the uplift involved not only the Sierra but the adjacent mass of the Great Basin. Ransome justly points out that the detrital masses from the enormous early Cretaceous erosion of the Sierra Nevada were deposited mainly on the site of the present Coast Ranges and only to a smaller degree in the Great Valley itself. As shown in this report, the first breaks along the eastern fault system were outlined during the Cretaceous period, but at a distance from the main deposits that would seem to preclude any direct connection between the sedimentation and the faulting.

Erosion continued in the Sierra Nevada during the whole of the Tertiary, but at so slow a rate that no sediments of excessive thickness could have been deposited in the Great Valley.

The orogenic movement took place at the end of the Tertiary, and here, again, the incompetency of the supposed cause is apparent. Indeed, in the last part of the Tertiary the range itself became loaded by volcanic material flowing down over its slope from volcanoes at or east of the summit, to an extent which probably much more than balanced the amount removed by erosion during the whole of the Tertiary.

The epoch of erosion that began immediately after the close of the volcanic flows unquestionably removed an enormous load from the range and deposited it in the Great Valley. The valley gradually subsided, at least in that part adjacent to the territory here considered, as shown by the absence of débris fans from the Sacramento Valley, but that the subsidence is due to the weight of the sediments is a hypothesis pure and simple. No corresponding elevation of the Sierra Nevada has taken place in Quaternary time. The numerous and great oscillations of the shore line along the valley border (see pp. 21–28) have also taken place independently of loading or unloading and constitute a strong argument against isostatic movements by erosion or sedimentation.

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[1] Ransome, F. L., The Great Valley of California, a criticism of the theory of isostasy: Bull. Dept. Geology, Univ. California, vol. 1, No. 14, 1896, pp. 371–428.

[2] Structure of a portion of the Sierra Nevada: Bull. Geol. Soc. America, vol. 2, 1891, pp. 49–74.

The problem of the origin of the epeirogenic movements, then, is removed from the field of superficial phenomena and becomes a problem of astronomy and geophysics with which the ordinary geologist is scarcely qualified to deal. Deep-seated the causes were, beyond a doubt, for uplift of a continent involving the tilting of a marginal heterogeneous block 80 miles wide and 300 miles long, with no or at most inconspicuous deformation, must have required forces acting through depths of miles. The establishment of the actual westward tilting and the almost perfect rigidity of the Sierra Nevada during this movement is probably the most important scientific result of these investigations.

CHAPTER 3. FOSSILS OF THE TERTIARY AURIFEROUS GRAVELS.

INTRODUCTION.

The fossils found in the Tertiary gravels of the Sierra Nevada comprise mammal remains, including doubtful human bones, associated with which objects of human handiwork are said to have been found; fossil leaves, which in places are very abundant and well preserved; and diatoms, which occur in abundance in several of the so-called "infusorial earths" in association with rhyolitic tuffs. As will be shown in the following pages, the testimony on which dependence can be placed is confined almost exclusively to the fossil plants and the paleontologic determination of age must therefore be furnished by paleobotany.

MAMMAL REMAINS.

Whitney, in his volume on the auriferous gravels, gives a list of all the mammal remains which have been found and determined and divides this list into two parts, the first comprising localities in which the bones were found in known and undisturbed Tertiary deposits and the second and larger part including those occurrences in which the geologic formation was less satisfactorily determined. The number of species of clearly prevolcanic occurrence is not large. The most important localities are Douglas Flat and Chili Gulch, in Calaveras County, and the Tuolumne Table Mountain, not far to the south, in Tuolumne County. In the Calaveras County localities bones and teeth of a species of rhinoceros, described by Leidy[1] under the name *R. hesperius*, have been discovered. At Douglas Flat was also found a tooth of the pachyderm *Elotherium*, which belongs to the Eocene or Oligocene (White River group of the Rocky Mountain region): The material in which this fossil was found is not described. These few occurrences complete the list of fossils which Whitney considered authentic and beyond doubt derived from the Tertiary gravels. Among the less certain occurrences are those of Kincaid Flat, near Sonora, where molars of *Bos latifrons* are stated to have been found at a depth of 18 feet in the auriferous detritus of that locality. At a number of places in the vicinity of Sonora and Columbia, along a belt of limestone, fossil bones have been found in the clay filling crevices or spaces of dissolution. These fossils belong principally to the well-known species *Mastodon americanus*. One other species of this genus (*M. obscurus*) has been discovered at Dry Creek, in Stanislaus County. At Gold Spring, near the locality mentioned above, a few miles from Sonora, a great quantity of bones were heaped together. A tooth of *M. americanus* was also found at a depth of 48 feet at Douglas Flat. This tooth, however, did not appear as thoroughly fossilized as the rhinoceros jaw found in the same locality, said to have come from a great depth in the gravel, which in places is probably over 200 feet thick.

A number of elephant remains, consisting principally of molar teeth, have been discovered in the Sierra Nevada; among the localities is a place near Murphy, in Calaveras County, where they were found at a depth of about 30 feet in the auriferous detritus overlying the limestone. An excellent specimen, more complete than usual, was found, according to Whitney, near Fresno River, 3 miles above the crossing of the stage road from Hornitos to Visalia. The remains were covered by only 3 or 4 feet of sandy alluvium. All these remains are believed to belong to *Elephas americanus* or to its variety, *E. columbi*.

Leidy has identified remains of *Equus excelsus* Leidy or *E. occidentalis* Leidy, from 20 feet below the surface at Columbia, Tuolumne County; also at Matlock Gulch, in the same county. *Equus caballus* is reported from Texas Flat, Kincaid Flat, and Columbia, Tuolumne County; also at Brandy City, Sierra County. The skull found at Brandy City was labeled "from

[1] Leidy, Joseph, Contributions to the extinct vertebrate fauna of the western Territories: U. S. Geol. Survey Terr., vol. 1, 1873.

auriferous gravel, 35 or 40 feet below the surface." Several molars from the various localities in Tuolumne County are said to have come from depths of 5 to 29 feet.

Imperfectly preserved bones of horses of indeterminable species are reported from the Table Mountain, Tuolumne County, where they were said to be found underneath the lava at a depth of 210 feet; another locality is at Soulsbyville, Tuolumne County, where the remains were stated to occur beneath the volcanic rocks, in gravel resting upon granite.

This is practically the whole record. Very few finds have been reported since Whitney wrote his volume on the auriferous gravels.

Most of the localities referred to between Sonora, Columbia, and Gold Spring are extremely doubtful. The gravel is not covered by volcanic rocks and the region has remained without very great topographic changes, aside from the cutting of the deep canyon of the Stanislaus, since late Tertiary time. In most places in this region it is entirely impossible to separate the Tertiary from the Quaternary gravels. The writer believes that the remains of *Bos*, *Mastodon*, and *Elephas* were really found in Quaternary deposits; the occurrence of *Elephas* on Fresno River is, of course, assuredly Quaternary. It is equally difficult to express a positive conclusion as to the several species of *Equus* said to have been discovered in the auriferous gravels.

An interesting locality mentioned by Whitney is on a nameless dry creek tributary to Bear Creek, in Merced (now Madera) County, near the line of Mariposa County, about 6 miles southwest of Indian Gulch. Whitney says that the rocks at this place consist of a coarse friable light-colored volcanic ash, which envelops a large quantity of bones. "The most striking of the bones found here were those of an extinct llama, much larger than the ordinary camel. With these were associated bones of the deer and those of one or more species of horse, together with others which could not be determined." [1] Leidy gave to this species of llama the name *Auchenia californica*. Nothing is known as to the geologic relations at this place.

The species which can be said with some confidence to have been derived from the Tertiary gravels are confined to *Rhinoceros hesperius* and *Elotherium superbum*, and these, especially the latter, would, according to the paleontologists, indicate Eocene or Miocene age.

Among other vertebrate remains those of tortoises should find mention; they have been described and their geologic horizon carefully indicated by W. J. Sinclair.[2] One specimen was found in gravel of the rhyolitic epoch 2 miles below Vallecito, Calaveras County, on the Parrott Ferry road, from 10 to 15 feet above the bedrock, at a gravel mine on Balaklava Hill. The tortoise is described as *Stylemys calaverensis*. Sinclair states that, similar remains have been found near Cave City, at a placer mine near San Andreas, and at other places. For the determination of the geologic horizon these fossils have little value.

It remains to discuss the human remains and the specimens of human handiwork which are said to have been found in the Tertiary gravels. J. D. Whitney published in his work on the auriferous gravels a number of important data tending to establish the existence of man at the time of the Tertiary gravels of California. He stated that many relics of the handiwork of man had been discovered in these gravels; they include mortars and pestles, grooved pebbles, flat dishes, and arrow heads, the mortars being the most common forms. Human remains, as reported from the gravels, are not abundant; the best evidence consists of an imperfect human cranium, the famous "Calaveras skull." Whitney examined the evidence with great minuteness and came to the conclusion that man must have existed in the Sierra Nevada during the late Tertiary epoch. Since the publication of Whitney's book further data tending in the same direction have been submitted by G. F. Becker.[3] In 1901 the whole evidence relating to auriferous-gravel man in California was reviewed by William H. Holmes from the standpoint of both the geologist and the ethnologist.[4] Holmes examined the evidence regarding the famous Calaveras skull with great care and personally inspected the fossil at the museum at Harvard University. He concluded that the skull was never carried and broken in a Tertiary

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[1] Auriferous gravels, 1879, p. 248.
[2] A new tortoise from the auriferous gravels of California: Bull. Dept. Geology Univ. California, vol. 3, No. 11, 1903, pp. 243-248.
[3] Antiquities from under Tuolumne Table Mountain in California: Bull Geol. Soc. America, vol. 2, 1891, pp. 189-198.
[4] Review of the evidence relating to auriferous gravel man in California: Smithsonian Rept. for 1899, pp. 419-472.

torrent, that it never came from the old gravels in the Mattison mine, that it does not in any way represent a Tertiary race of men, and that if the existence of Tertiary man in California is finally proved it will be on evidence other than that furnished by the "Calaveras skull." Notwithstanding this decided opinion, Holmes believes that with respect to the existence of Tertiary man in California no final conclusion can yet be drawn. The strongest evidence consists in the various implements found, and regarding these he summarizes the arguments for and against great antiquity about as follows:

Although many of the objects came from surface mines some were apparently derived from tunnels or inclines underneath the lava capping. They were, as a rule, found by miners, but the statements of discovery are reasonably clear and show no attempted deception. The reported finding of an implement in place in the gravels underlying Table Mountain by Clarence King is especially important and gives countenance to the reports of inexpert observers. The intimate association of many of the human remains with those of extinct animals is noted. The evidence, as presented by Whitney, seems abundant and convincing. It is clearly the strongest body of evidence yet brought together tending to connect man with any geologic formation earlier than postglacial.

On the other hand, the existence of a Tertiary man, even of the lowest grade, has not yet been fully established in any country. The California evidence implies a human race much older than that of *Pithecanthropus erectus* of Dubois, which may be regarded as an incipient form only of human creature. The finds reported indicate a people well advanced in culture. The crania recovered are identical in character with recent crania. The objects of art are found to belong to the polished-stone stage and to duplicate modern implements in every essential respect. They are such as may have fallen in from Indian camp sites or been carried in by the Indians themselves. Indian tribes have occupied the region for centuries and buried their dead in pits, caves, and deep ravines, where the remains were readily covered by débris or calcareous matter deposited by water. The region has been extensively dug over by the miners and many of the old ossuaries were worked and old village sites undermined; by this means thousands of the native implements were introduced into the mines and became intermingled with the gravels. Implements and utensils may also have been introduced into the deep mines by the Indians hired as helpers in the mining work. The testimony is derived almost wholly from inexpert observers, and all observations were recorded at second hand.

But a short time before Holmes published his conclusions W. P. Blake wrote a short paper in which he confessed that the whole evidence of Tertiary man in California seemed utterly insufficient to him.[1] In 1908 Sinclair, after personal investigation, reviewed the evidence and came to the same conclusion.[2]

The writer is wholly in accord with the conclusions of Holmes and Blake and believes that the testimony is weak and insufficient. A number of the objects illustrated by Holmes came from localities formerly referred to as in the vicinity of Sonora and Columbia, where so many mammal remains have been found. The gravels where these occur the writer believes to be mainly Quaternary, and it should be noted that the material of which most of the mortars are made is andesite, apparently identical with the rock composing the flows that cover the auriferous gravels. During the gravel period such andesites were probably not to be found in any part of California, certainly not close to the region in question. Other implements figured by Holmes—for instance, those from Oregon Bar, Placer County; or Spanish Flat, Eldorado County; or Horseshoe Bend, Mariposa County[3]—are assuredly from Quaternary strata.

In 1901 J. M. Boutwell, then of the Geological Survey, accompanied the writer to investigate the channels of Calaveras County. In the vicinity of the place where the Calaveras skull is said to have been found Mr. Boutwell gathered from old residents some interesting testimony which supplements that of Holmes and tends toward the same conclusions. His account is herewith appended.

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[1] Blake, W. P., The Pliocene skull of California and the stone implements of Table Mountain: Jour. Geology, vol. 7, 1899, pp. 631-637.

[2] Sinclair, W. J., Recent investigations * * * on the occurrence of Neocene man, in the auriferous gravels of the Sierra Nevada: Univ. California pub., American archeology and ethnology, vol. 7, No. 2, 1908, pp. 108-137.

[3] Holmes, W. H., op. cit., Pls. VIII, IX, X, and XI.

THE CALAVERAS SKULL.

By J. M. Boutwell.

About half a mile northeast of Altaville, at Bald Hill, is the locality in which the "Calaveras skull," described by Whitney, was reported to have been discovered in stream gravels overlain by Tertiary tuffaceous lavas. Inasmuch as the authenticity of this skull is still open to discussion, the original information procured in the course of the present study is pertinent. Bald Hill is a lenticular, moundlike knob trending northeast and southwest, somewhat over 100 feet in height. The longitudinal section from northeast to southwest shows, lying upon bedrock at the west end and forming the west rim at an elevation of 1,590 feet, the following section:

Section at Bald Hill.

	Feet.
Rhyolitic mud	4
Rhyolitic tuff	8
Unconformity by erosion.	
Washed volcanic gravels and sands, pink and white rhyolitic pebbles	12–15
Covered	10
Tuffaceous sand	5
Rhyolitic tuff	50
Washed porphyritic and volcanic gravels	30
Bedrock.	

Near the top of the knob are two dumps, one made up of some rhyolitic tuff, much andesitic tuff, and considerable quantities of well-washed siliceous and porphyritic gravels. Just beyond and sunk in the gravels forming the top of the hill is the second shaft, which penetrates, to judge from the dump, siliceous and porphyritic gravels, probably some rhyolite, and possibly some andesite. The second dump appears to be much the older, and thus in all probability is the one from which the Calaveras skull is stated to have been taken. The writer was fortunately able to interview old residents of the region, including one of the three living principals in the affair, Mr. S. F. Schaeffle, an intimate friend of a second one of the principals, and to check the statements of these men by other reliable first-hand information. This accordant testimony may be briefly summarized as follows:

At the time of the event under discussion some very perfect trunks of palms were found in workings in gravels at Bald Hill. This was unusual and occasioned considerable talk and discussion. About this time also a stream in Salt Spring Valley in cutting away its banks exposed an old Indian burying ground and washed out some skeletons. Dr. Kelly, one of the local physicians, obtained one of these skeletons and had it on exhibition in his office. One Ross Coon, who had become noted as the local joker through his many humorous acts, some of them of such character that he was cited to appear in court to answer for them, saw an opportunity for another joke. Another local doctor named Jones, who was an amateur scientist and a friend of the State geologist, J. D. Whitney, had a collection of specimens of odd and interesting things, including many old bones, and so was commonly regarded as somewhat of an authority on the subject of fossils. It is stated that the finding of the palms, the discovery of the Indian skeleton, and the presence of the eager doctor collector led to the hatching of a plot. Coon and Scribner (the second conspirator) are said by Schaeffle to have taken the skull from Dr. Kelly's office and had it placed (some say by one Siebold) in gravels in the shaft then being sunk on Bald Hill by a man named Mattison. Then, either Dr. Jones was asked to visit the locality and observe the skull reported to have been found, or it was removed by Mattison and sent to him at his own request by Scribner's partner. Dr. Jones is said to have accepted it as authentic, and in order to carry the joke further a description of the skull was written by Siebold and published in a newspaper. At this point Prof. Whitney, the State geologist, was invited to investigate the matter. The joke was assuming a more serious phase, but to carry it through and to protect Jones in the eyes of his friend Whitney both Scribner and Mattison gave testimony regarding their respective parts in the discovery, to the general

purport that the skull was authentic. Thus the skull came into the hands of Prof. Whitney, and the practical joke was accepted in good faith as a scientific discovery of the highest import.

In further corroboration of critical points Mr. Schaeffle, who worked in the shaft at the time, stated to the writer that he is of the opinion that the skull is the same one he had previously seen in Dr. Kelly's office; that it was not incrusted, nor did it in any way have the appearance of the gravel at the point where it was said to have been found, but that it was, on the other hand, black like many skulls found in the marshy burying grounds; that no other bones were ever found in the Bald Hill workings; and finally that he is "satisfied that it [the skull] never came out of that shaft originally." Again, Dr. Kelly told Mr. Schaeffle that he was confident the skull was the same one he had in his office before the reported discovery; that there was no Bald Hill gravel in or around the skull after being taken from the shaft, only black earth and some gravel totally unlike the Bald Hill gravel. All these statements are exactly corroborated by Mattison, who was an intimate friend of Coon's.

This explanation, as roughly outlined above, seems to represent the prevailing opinion of contemporary residents and friends of the perpetrators of the joke throughout that region. It should be stated, however, that two men, Mr. D. D. Demorest, owner of the shaft, and his son, do not share this opinion. Being employers, they were not in the joke, and then, as now, they were not intimate with the perpetrators. They were away during the present investigation, but are reported to believe in the authenticity of the skull.

DIATOMS.

During the early part of the Tertiary there was little opportunity for the development of organisms which live in still water. In the later volcanic period, however, when the valleys were filled with silt and volcanic mud, chiefly of rhyolitic origin, there were many places where the current must have been almost stagnant and temporary lakes may have existed. In these lakes fine-grained light-colored deposits, which represent all transitions between a clay and a volcanic tuff and which contain large quantities of the siliceous remains of diatoms, minute and simply organized plants, are frequently found. These partly consolidated deposits are often classed under the name infusorial earth and are sometimes employed for polishing purposes. Infusorial earth, rich in remains of diatoms, has been found at numerous localities, chiefly on the middle slopes of the Sierra Nevada—for instance, near Placerville, on the Long Canyon divide, and at several places on the Forest Hill divide—and has been described in some detail by J. D. Whitney.[1] These vegetable remains have no value in determining the age of the strata in which they occur, and hence it seems unnecessary to devote further space to this subject.

TERTIARY FOSSIL PLANTS.

As the Sierra Nevada has remained a land area at least since the early part of the Cretaceous period, it would not be surprising to find the remains of plants in the land deposits which have accumulated on its surface and which would be supposed to range from the Cretaceous to the Quaternary. It appears, however, that physiographic changes have obliterated all deposits of Cretaceous age and that the remains of plants discovered in the prevolcanic gravels, as well as in those of intervolcanic age, have proved to be of Tertiary type. A great deal of detailed work on this subject has been done by paleobotanists, chiefly by Lesquereux and Knowlton, and the earlier part of the work is summarized by Whitney in his volume on the auriferous gravels. The later work has been summarized by Prof. Knowlton in a paper forming a part of this chapter. It will be unnecessary, therefore, to enter into detail at this place. The determinable fossils consist almost wholly of leaves which, in places, have been preserved with extraordinary detail in the fine-grained sediments that cover the coarser gravels. Fossil wood is also extremely abundant at all horizons, but the species can rarely be determined with accuracy from such material. In a number of the intervolcanic channels, many of which were suddenly filled by slowly moving streams of volcanic mud, trunks of trees have been found

[1] Auriferous gravels, 1879, pp. 219–231.

remaining in an upright position, with their roots in the gravel and a large portion of the trunk preserved in the volcanic tuff. Remains of this kind were observed in 1901 by the writer in the Weske tunnel on the Forest Hill divide, in Placer County. Browne[1] mentions the same occurrence and states that a number of "oak and cedar trees" were observed in this position, one of them nearly 100 feet in height and 4 feet in diameter at its base. He also says that such standing trees were found in the Bowen mine in the same channel and mentions similar occurrences in the intervolcanic channels near Deadwood, in Placer County. The andesitic tuff and tuff-breccia are also locally rich in casts of sticks and stems of fossil wood.

The consistent evidence from all the fossil localities shows that the climate of this region in Tertiary time was like that of the southern temperate zone of the Atlantic coast region to-day. Species like those of laurel, maple, beech, fig, magnolia, walnut, and oak predominated and the climate was assuredly characterized by heavy rainfall. Whitney pointed out that there was no material difference in character between the floras collected from strata near the present sea level and those collected from points 6,000 or 7,000 feet above the sea, but he did not fully recognize that the cause of this similarity lay in the extensive late Tertiary tilting of the Sierra Nevada. Differences of level existed, of course, then as now, but were not nearly as pronounced, the highest summits rising probably not more than 4,000 or 5,000 feet above the Tertiary sea level.

F. H. Knowlton expresses a final conclusion that the flora of the auriferous gravels indicates a Miocene age. One collection, however, differs somewhat from the rest. It was obtained by J. S. Diller from the vicinity of Susanville, in Lassen County, near the base of the auriferous gravels, which are there exposed in an exceptionally thick series. The locality is situated near the place where a large northward-draining river emptied into a broad estuary or bay. Prof. Knowlton believes that this collection clearly indicates an Eocene age.

As shown in previous pages, the period of deposition of the auriferous gravels was long and includes several well-defined formations. The deepest gravels, of prevolcanic age, are coarse and have yielded no fossils, nor are there any valley deposits which have been shown to be contemporaneous with them. It is probable that the collection from Susanville, mentioned above, comes from strata equivalent in age to these deep gravels and that they were deposited in Eocene time. Above the deep gravels lie bench gravels of finer texture and these are immediately overlain by thick clays and rhyolitic tuffs. At these horizons were found the great collections from Chalk Bluffs and Independence Hill (see fig. 11, p. 148), which form the most important part of the testimony. The valley deposits, corresponding to the bench gravels, are called the Ione formation, and the available evidence, though not extensive, indicates that this formation is of the same Miocene age. In Prof. Knowlton's list the Volcano Hill collection represents this horizon, and north of the fortieth parallel Diller has collected fossil leaves which confirm this conclusion. The localities are at Little Cow Creek, in the southeastern part of the Redding quadrangle, and near the head of Kosk Creek, in the Lassen Peak quadrangle. In this region the Ione lies at a higher elevation than elsewhere and Diller believes that underneath the andesite it sweeps around the north end of the Sierra Nevada. The species identified, which are not comprised in Knowlton's list on pages 61–62, though they were determined by him, are as follows:[2]

Little Cow Creek.	*Near head of Kosk Creek.*
Ficus asiminæfolia? Lesq.	Sabalites californicus Lesq.
Populus zaddachi? Heer.	Ulmus californica Lesq.
Platanus dissecta Lesq.	Ficus tiliæfolia Al. Br.
Laurus californica? Lesq.	Populus zaddachi Heer.
Salix n. sp.	Quercus convexa Lesq.
Cinnamomum n. sp.	Fagus antipofii Abich.
Zizyphus n. sp.	Persea pseudo-carolinensis Lesq.
	Laurus sp.
	Magnolia californica Lesq.
	Rhus mixta Lesq.

[1] Browne, R. E., Ancient river beds of the Forest Hill divide: Tenth Ann. Rept. California State Mineralogist, 1890, p. 441.
[2] Diller, J. S., Redding folio (No. 138), Geol. Atlas U. S., U. S. Geol. Survey, 1906.

Knowlton remarks that the collection indicates a Miocene age and that nothing in it suggests an age as old as the Eocene.

At a few places bivalves have been found with fossil leaves. Diller found a *Unio* on Little Cow Creek; farther south, near the Oroville Table Mountain, Turner discovered a *Corbicula* in the same formation. In the Marysville Buttes the present writer collected a number of marine fossils from beds believed to represent the Ione.[1] These fossils were regarded by Dall and Stearns as Miocene. The list is as follows:

Crassatella collina Conrad.
Venericardia borealis Conrad.
? Verticardia sp.
Acila castrensis Hinds.
Liocardium apicinum Carpenter.
Fusus (Exilia) sp.
Macoma sp.
Tapes (Cuneus) sp.
Saxidomus sp.
Cardium (Fulvia) modestum.
Galerus sp.

Small collections of leaves have been made from tuffs and clays in the interandesitic channels—that is, those which were excavated and filled during the epoch of andesitic eruptions. Specimens have also been collected by H. W. Turner from the beds laid down in the Tertiary Mohawk Lake, which are covered by andesite but lie in a deep depression formed by faulting since the deposition of the earlier gravels. It has not been possible to recognize any distinction in age between these beds and those of the bench gravels from which the principal collection came. According to present evidence, then, nearly the whole of the auriferous gravel series, from the top of the deep gravels to the latest andesitic flows, were deposited during the Miocene epoch. The deep gravels are recognized as probably Eocene.

FLORA OF THE AURIFEROUS GRAVELS OF CALIFORNIA.

By F. H. KNOWLTON.

INTRODUCTION.

The auriferous gravels of California have been the subject of prolonged discussion as regards their geologic history, one of the most important points being the determination of their age. In the present chapter I have attempted to summarize the knowledge at present available regarding the bearing of the flora in fixing the position of these gravels in the time scale. Unfortunately I have not had sufficient time in which to study completely all of the material now in hand, but it seems improbable that subsequent study will greatly modify the results here set forth.

Before considering the plants it may be well to enumerate the localities which have afforded floras and to indicate briefly their presumed stratigraphic position.

1. Chalk Bluffs, near You Bet, Nevada County, on the main channel of the Neocene South Fork of the Yuba, at an elevation of about 3,000 feet. It is not possible to fix absolutely the position of the plant beds, as the locality is now much obscured by sliding débris, though, according to Mr. Lindgren, it is certain that the plants came from either the uppermost bench gravels or the lowest rhyolitic tuffs, at a point approximately 500 feet above the bottom of the old channel.
2. Washington gravel mine, Independence Hill, near Iowa Hill, Placer County. The plants come from the uppermost gravels of the antevolcanic period.
3. Volcano Hill, Placer County. Thought to be of the same position and age as Chalk Bluffs.
4. Monte Cristo gravel mine, summit of Spanish Peak, Plumas County. The leaves are from a bed overlain by andesite and belonging therefore to the intervolcanic period.
5. Mohawk Valley, Plumas County. Neocene lake beds containing rhyolitic fragments and overlain by andesite tuffs, hence intervolcanic.
6. Bowen's tunnel 2 miles north of Michigan Bluffs, Placer County. Apparently in the upper rhyolitic tuffs or gravels and just antedating the main andesitic flows.
7. North Fork tunnel, on North Fork of Oregon Creek, near Forest City, Sierra County; 20 miles north of Chalk Bluffs. Position and age apparently similar to the last, namely, intervolcanic.
8. Table Mountain, Tuolumne County. This locality is apparently in the upper part of the andesitic flows—that is, interandesitic.
9. Corral Hollow, Alameda County. Apparently overlain by andesitic tuffs, therefore intervolcanic.

[1] Lindgren, Waldemar, Marysville folio (No. 17), Geol. Atlas U. S., U. S. Geol. Survey, 1895.

10. South of Mount Diablo, Contra Costa County Position presumed to be similar to the last.
11. About 7½ miles southwest of Susanville, Lassen County.
12. North end of Mountain Meadows, Lassen County.
13. Near Moonlight, Lassen County.

The earliest known localities which afforded most of the material studied by Lesquereux are Chalk Bluffs, Nevada County; Table Mountain, Tuolumne County; Bowen's tunnel, Placer County; and North Fork tunnel, near Forest, Sierra County. Most of this material, including the types and a considerable number of duplicates, is preserved in the University of California, where, by the courtesy of Dr. John C. Merriam, I was able to see and study it.

A REVISION OF LESQUEREUX'S "FOSSIL PLANTS OF THE AURIFEROUS GRAVEL DEPOSITS OF THE SIERRA NEVADA."[1]

Sabalites californicus Lesquereux; op. cit., p. 1, Pl. I, fig. 1. This specimen was not found in the museum of the University of California, and the locality given by Lesquereux may or may not be correct. Locality: Chalk Bluffs, Nevada County (?).

Betula æqualis Lesquereux; op. cit., p. 2, Pl. I, figs. 2–4 (Nos. 1855, 1856, 1857, Mus. Univ. California). Types all seen. Locality: Chalk Bluffs, Nevada County.

Fagus antipofi Heer; op. cit., p. 3, Pl. II, fig. 13 (No. 1914, Mus. Univ. California). This leaf, of which only the base is present, is strongly suggestive of both *Quercus olafseni* [2] and *Q. nevadensis*,[3] but seems to differ in being a thicker leaf with a heavier midrib and very numerous, close, strong nervilles. Locality: Table Mountain, Tuolumne County.

Fagus pseudo-ferruginea Lesquereux; op. cit., p. 3, Pl. II, fig. 14 (No. 1898, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Quercus elænoides Lesquereux; op. cit., p. 4, Pl. I, figs. 9–12. Only two of the types could be found in the Museum of the University of California—the originals of figures 9 (No. 1922) and 11 (No. 1975). Locality: Table Mountain, Tuolumne County, and Bowen's tunnel, near Forest, Sierra County.

Quercus convexa Lesquereux; op. cit., p. 4, Pl. I, figs. 13–17 (Nos. 1869–1873, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Quercus nevadensis Lesquereux; op. cit., p. 5, Pl. II, figs. 3, 4 (Nos. 1860, 1861, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Quercus boweniana Lesquereux; op. cit., p. 6, Pl. II, figs. 5, 6 (No. 1965, Mus. Univ. California). Locality: Bowen's claim=Bowen's tunnel, 2 miles north of Michigan Bluff, Placer County (?).

Quercus distincta Lesquereux; op. cit., p. 6, Pl. II, figs. 8, 9 (fig. 8, No. 1865; fig. 9, No. 1866, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Quercus göpperti Lesquereux; op. cit., p. 7, Pl. II, fig. 11 (No. 1853, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Quercus voyana Lesquereux; op. cit., p. 8, Pl. II, fig. 12 (No. 1897, Mus. Univ. California). Locality said to be Chalk Bluffs, Nevada County, but uncertain. In any event it is not a well-marked species, consisting simply of the basal portion of a small leaf.

Castaneopsis chrysophylloides Lesquereux; op. cit., p. 9, Pl. II, fig. 10 (No. 1854, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Salix californica Lesquereux; op. cit., p. 10, Pl. I, figs. 18–21 (Nos. 1875–1878, Mus. Univ. California.) Locality: Table Mountain, Tuolumne County.

Salix elliptica Lesquereux; op. cit., p. 10, Pl. I, fig. 22. Type not found. Said to be from Chalk Bluffs, Nevada County.

Populus zaddachi Heer; op. cit., p. 11, figs. 1–8 (Nos. 1817, 1819–1823, Mus. Univ. California). This species is abundant, there being not less than a dozen more or less perfect leaves besides the ones figured. With the exception of the leaf shown in figure 6, all seem to be fairly uniform in shape and general character. This particular leaf is much narrower and more wedge-shaped at the base and should probably be referred to *Zizyphus piperoides* Lesquereux (p. 59). Locality: Chalk Bluffs, Nevada County.

Platanus appendiculata Lesquereux; op. cit., p. 12, Pl. III, figs. 1–6; Pl. VI, fig. 7[b] (Nos. 1843–1846, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Platanus dissecta Lesquereux; op. cit., p. 13, Pl. VII, fig. 12; Pl. X, figs. 4, 5 (Nos. 1831, 1832, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Liquidambar californicum Lesquereux; op. cit., p. 14, Pl. VI, fig. 7[c]; Pl. VII, figs. 3, 6 (Nos. 1840, 1841, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Ulmus californica Lesquereux; op. cit., p. 15, Pl. IV, figs. 1, 2; Pl. VI, fig. 7[a] (Nos. 1915, 1916, Mus. Univ. California). All the types of this species are present in the University of California, as well as 20 or more additional examples.

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[1] Mem. Mus. Comp. Zool. Harvard Coll., vol. 6, No. 2, 1878, pp. i–vi, 1–62, Pls. I–X. As all references in the following list are to this publication the complete citation is not repeated under each species.

[2] Lesquereux, Leo, The Cretaceous and Tertiary floras: Rept. U. S. Geol. Survey Terr., vol. 8, 1883, p. 245, Pl. LIV, fig. 3.

[3] Idem, Pl. II, figs. 3, 4.

They agree fairly well among themselves, although there is considerable range in size. Lesquereux describes them as having the "borders irregularly denticulate." The types do not show this (the figures being slightly wrong), but have the margin somewhat doubly serrate as described for *U. affinis*. Locality: Chalk Bluffs, Nevada County.

Ulmus pseudo-fulva Lesquereux; op. cit., p. 16, Pl. IV, fig. 3. The types of this species is probably at Harvard.

Ulmus affinis Lesquereux; op. cit., p. 16, Pl. IV, figs. 4, 5. The types of this species could not be found. Figure 5=*U. californica;* figure 4 is doubtful. It has, according to the figure, a long petiole, a somewhat wedge-shaped, base and closer parallel secondaries. It may be a good species.

Ficus sordida Lesquereux; op. cit., p. 17, Pl. IV, figs. 6, 7 (Nos. 1812, 1813, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

? *Ficus tiliæfolia* Al. Braun; op. cit., p. 18, Pl. IV, figs. 8, 9 (Nos. 1814, 1815, Mus. Univ. California). Beyond the fact that these leaves are somewhat smaller than those of *F. sordida* and slightly unequal-sided at the base, they show absolutely no difference. They have the same thick petiole, the same number of basal ribs, and the same manner of branching in the lowest pair of ribs, and the nervilles and finer nervation, so far as can be made out, are identical. I should incline to regard them as belonging to *F. sordida*. Locality: Chalk Bluffs, Nevada County.

Ficus microphylla Lesquereux; op. cit., p. 18, Pl. IV, figs. 10, 11 (Nos. 1809, 1810, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Persea pseudo-carolinensis Lesquereux; op. cit., p. 19, Pl. VII, figs. 1, 2. *Magnolia californica* Lesquereux; op. cit., p. 25, Pl. VII, fig. 5 (not figs. 6, 7). All these leaves are in the Museum of the University of California (Nos. 1802–1804). The example referred to *Magnolia californica* by Lesquereux is absolutely identical with *Persea pseudo-carolinensis* (Pl. VII, fig. 2), having the same secondaries and characteristic fine nervation. Both examples of *P. pseudo-carolinensis* are said by Lesquereux to be from Table Mountain, but figure 1 is from Chalk Bluffs. The example transferred from *Magnolia californica* is from Table Mountain.

Aralia whitneyi Lesquereux; op. cit., p. 20, Pl. V, fig. 1 (No. 1838, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Aralia zaddachi? Heer; op. cit., p. 21, Pl. V, figs. 2, 3. Much confusion exists regarding Lesquereux's identification of this form. The fragmentary leaf shown in Plate V, figure 3, is a part of the same leaf as that figured by Lesquereux in the Cretaceous and Tertiary floras, Plate LIX, figure 3, under the name *Acer trilobatum productum*. Furthermore, the *Acer* portion of the leaf is said to have come from "Currant Creek, John Day Valley, Oregon," while the other (*Aralia*) portion comes from Table Mountain, California. The latter statement is correct, as the locality is so marked on the back of both pieces. This composite belongs to neither of the above genera but is probably to be referred to *Platanus dissecta* Lesquereux, although it does not agree in every particular.

Aralia angustiloba Lesquereux; op. cit., p. 22, Pl. V, figs. 4, 5 (Nos. 1904, 1905, Mus. Univ. California). The material on which these specimens are preserved is quite unlike the soft white material from Chalk Bluffs, being a very hard, heavy, nearly black ironstone, evidently a nodule. Locality: Chalk Bluffs, Nevada County.

Cornus ovalis Lesquereux; op. cit., p. 23, Pl. VI, figs. 1, 2 (Nos. 1902, 1903, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Cornus kelloggii Lesquereux; op. cit., p. 23, Pl. VI, fig. 3 (No. 1816, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Magnolia lanceolata Lesquereux; op. cit., p. 24, Pl. VI, fig. 6 (No. 1801, Mus. Univ. California). The nervation is said by Lesquereux to be "lost," but the nervilles are present and, as nearly as can be made out, are percurrent. Locality: Chalk Bluffs, Nevada County.

Magnolia californica Lesquereux; op. cit., p. 25, Pl. VI, figs. 6, 7 (not fig. 5, which=*Persea pseudocarolinensis;* see above. No. 1805, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Acer æquidentatum Lesquereux; op. cit., p. 26, Pl. VII, figs. 4, 5 (Nos. 1836, 1837, Mus. Univ. California). This eems more like a *Platanus* than an *Acer*, but in the absence of further information it may be allowed to remain as assigned by Lesquereux. Locality: Chalk Bluffs, Nevada County.

Acer bolanderi Lesquereux; op. cit., p. 27, Pl. VII, figs. 7–11 (Nos. 1825–1829, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Zizyphus piperoides Lesquereux; op. cit., p. 28, Pl. VIII, figs. 10, 11 (No. 1859, Mus. Univ. California). One figure of this leaf (fig. 10) is wrong—instead of the lower nerves coming around in a circle above the top of the petiole, as shown in the figure, they come down at a low angle. They do not curve around. The finer nervation consists of loose nervilles forming an open network. Locality: Chalk Bluffs, Nevada County.

Zizyphus microphyllus Lesquereux; op. cit., p. 28, Pl. VIII, fig. 9. Type not seen. Locality: Chalk Bluffs, Nevada County.

Ilex prunifolia Lesquereux; op. cit., p. 27, Pl. IX, fig. 7 (No. 1924, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Rhus typhinoides Lesquereux; op. cit., p. 29, Pl. IX, figs. 1–6 (Nos. 1889–1894, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Rhus boweniana Lesquereux; op. cit., p. 29, Pl. IX, figs. 8, 9. Types not seen. Locality unknown, supposed to be Table Mountain, Tuolumne County.

Rhus mixta Lesquereux; op. cit., p. 30, Pl. IX, fig. 13. Type not seen. Locality: Chalk Bluffs, Nevada County.

Rhus myricæfolia Lesquereux; op. cit., p. 31, Pl. I, figs. 5–8 (Nos. 1849–1852, Mus. Univ. California). Not all the types seen. Locality: Chalk Bluffs, Nevada County.

Rhus metopioides Lesquereux; op. cit., p. 31, Pl. VIII, figs. 12, 13 (Nos. 1867, 1868, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Rhus dispersa Lesquereux; op. cit., p. 32, Pl. I, fig. 23 (No. 1901, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

Zanthoxylon diversifolium Lesquereux; op. cit., p. 33, Pl. VIII, figs. 14, 15 (Nos. 1899, 1900, Mus. Univ. California). As Lesquereux pointed out, these leaves are very diverse in size and may represent two species, yet they have the same irregular shape and the same nervation. Locality: Table Mountain, Tuolumne County; not "Bowen's claim," as stated by Lesquereux.

Juglans californica Lesquereux; op. cit., p. 34, Pl. IX, fig. 14; Pl. X, figs. 2, 3 (Nos. 1863, 1864, 1881, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Juglans oregoniana Lesquereux; op. cit., p. 35, Pl. IX, fig. 10. This species, thought by Lesquereux to have come from Chalk Bluffs, is from Van Horn's ranch, John Day Valley, Oregon (cf. Knowlton, F. H., Bull. U. S. Geol. Survey, No. 204, 1902, p. 36).

Juglans laurina Lesquereux; op. cit., p. 35, Pl. IX, fig. 11. Type not seen. Locality: Chalk Bluffs, Nevada County.

Juglans egregia Lesquereux; op. cit., p. 36, Pl. IX, fig. 12; Pl. X, fig. 1 (No. 1862, Mus. Univ. California). Locality: Chalk Bluffs, Nevada County.

Cercocarpus antiquus Lesquereux; op. cit., p. 37, Pl. X, figs. 6–11 (Nos. 1882–1887, Mus. Univ. California). Locality: Table Mountain, Tuolumne County.

The following species are described but not figured in an appendix to Lesquereux's paper (pp. 59–62). They are supposed to be preserved in the Museum of Comparative Zoology, Cambridge, but I have not seen them. They all come from a tunnel near the Bald Mountain tunnel, on the north fork of Oregon Creek, near Forest City, Nevada County:

Quercus transgressus Lesquereux.
Quercus steenstrupiana? Heer.
Quercus pseudo-chrysophylla Lesquereux.
Acer arcticum Heer.
Acer species.

THE FLORA COLLECTED NEAR SUSANVILLE.

In point of time perhaps the next collection from the auriferous-gravel area was a small one made by J. S. Diller in 1885 or 1886, from a deep ravine about 7½ miles southwest of Susanville, Lassen County. This material was studied by Lesquereux,[1] who reported the presence of 15 species which he regarded as being of Eocene age. Additional material which has been collected by Mr. Diller and his assistants within the last few years from the same locality, though apparently at a higher horizon, has been worked up by the writer. As the recently collected material is almost wholly different from that first collected, it became a matter of great interest to go over the original collection, which is fortunately preserved in the United States National Museum, and verify or otherwise dispose of Lesquereux's determinations. This study has resulted in a number of changes and corrections to accord with the more modern understanding of the forms involved. The following is a list of the forms as now recognized:

Aralia lasseniana Lesq.
Magnolia inglefieldi Heer.
Magnolia hilgardiana Lesq.
Cinnamomum! scheuchzeri? Heer.
Leguminosites sp.
Oreodaphne litsæformis Lesq.
Quercus moorii Lesq.
Quercus olafseni? Heer.
Juglans rugosa Lesq.
Laurus grandis Lesq.
Laurus californica Lesq.

The other species recognized by Lesquereux are disposed of as follows:

Magnolia californica Lesq.=Magnolia inglefieldi.
Laurus socialis Lesq.=Laurus californica.
Cornus hyperborea Heer=Magnolia inglefieldi.
Oreodaphne heerii Gaud.=Oreodaphne litsæformis.
Ficus appendiculata Heer=Laurus grandis.
Phragmites œningensis Al. Br. Worthless; rejected.
Ephedrites sotzkianus Schimp. Locality wrong; rejected.
Alnus nostratum? Unger. Specific name wrong; specimen a mere fragment; rejected.

Of the eleven species above enumerated as found in the lower beds southwest of Susanville, two (*Aralia lasseniana* and *Oreodaphne litsæformis*) were described as new and have not been

[1] Proc. U. S. Nat. Mus., vol. 11, 1888, pp. 28–31.

found outside. Of the remaining eight forms only one (*Laurus californica*) occurs typically in the auriferous gravels, although another (*Laurus grandis*) has been found at Corral Hollow, Alameda County. Two species (*Magnolia hilgardiana* and *Quercus moorii*) came originally from the Eolignitic of Mississippi. *M. hilgardiana* has also been reported from the "Laramie" of Fishers Peak, New Mexico, and the Fort Union of Montana; *Q. moorii* is otherwise known only from the original locality. *Magnolia inglefieldi*, which came originally from the Miocene (or upper Eocene) of Greenland, has been reported doubtfully from the Mascall formation (Miocene) of the John Day Valley, Oregon. *Juglans rugosa*, on the other hand, enjoys a wide vertical distribution from the true Laramie through various post-Laramie beds into the Fort Union.

From this brief review it appears beyond reasonable question that the lower plant-bearing beds southwest of Susanville are probably below and slightly older than the typical auriferous gravels, hence are possibly in the upper Eocene. The matrix in which the plants are preserved is entirely different from any known in the auriferous gravels, being a much consolidated, rather hard blackish clay shale or slate, whereas that of the true auriferous gravels is usually a fine, soft clay or tuff.

SUMMARY OF PRESENT KNOWLEDGE OF THE FLORA.

We may now proceed to an enumeration and consideration of the auriferous gravel flora as at present understood, beginning first with a table showing the local as well as the outside distribution:

Distribution of the auriferous gravel floras.

	Local distribution.													Outside distribution.					
	Chalk Bluffs, Nevada County.	Independence Hill, Placer County.	Volcano Hill, Placer County.	Bowen's tunnel, Placer County.	Monte Cristo mine, Spanish Peak, Plumas County.	Mohawk Valley, Plumas County.	Near Forest, Sierra County.	Table Mountain, Tuolumne County.	Corral Hollow, Alameda County.	South of Mount Diablo, Contra Costa County.	7½ miles southwest of Susanville, Lassen County.	North end Mountain Meadows, Lassen County.	Moonlight, Lassen County.	Laramie.	Post-Laramie.	Fort Union.	Green River	Eocene.	Miocene.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Acer æquidentatum Lesq	×	×													×		×		
Acer arcticum Heer							×									×			
Acer benderei Lesq					×														×
Acer bolanderi Lesq					×			×											
Acer, fruit of		×																	
Acer sp. Lesq							×												
Æsculus n. sp. Kn		×																	
Æsculus n. sp. Kn		×																	
Alnus corrallina Lesq										×									
Aralia angustiloba Lesq	×	×																	
Aralia whitneyi Lesq	×	×									×					×		×	×
Arisæmites sp. Kn		×																	
Artocarpus californica Kn		×																	
Betula æqualis Lesq	×	×																	
Betula elliptica Lesq										×									
Betula parce-dentata Lesq										×									
"Carya bilinica Heer"					×														
Castanea castaneæfolia (Ung.) Kn		×																×	×
Castanea ungeri Heer									×										
Castanea sp													×						
Castanopsis chrysophylloides Lesq	×	×																	
Cercocarpus antiquus Lesq		×						×											
Cinnamomum cf. affine Lesq									×?					×					
Cinnamomum n. sp.?												×	×						
Colutea bowenlana Lesq				×															
Cornus hyperborea Heer		×																	
Cornus kelloggii Lesq	×																		
Cornus ovalis Lesq		×						×											
Equisetum sp. Lesq										×									
Equisetum sp. Lesq									×										
Equisetum? sp		×																	
Fagus antipofi Heer								×								×		×	
Fagus pseudo-ferruginea Lesq	×																		
Ficus asiminæfolia Lesq		×							×							×			×
Ficus microphylla Lesq		×						×											
Ficus cf. F. multinervis Heer		×																	
Ficus sordida Lesq	×	×	×?																×

Distribution of the auriferous gravel floras—Continued.

	Local distribution.													Outside distribution.					
	Chalk Bluffs, Nevada County.	Independence Hill, Placer County.	Volcano Hill, Placer County.	Bowen's tunnel, Placer County.	Monte Cristo mine, Spanish Peak, Plumas County.	Mohawk Valley, Plumas County.	Near Forest, Sierra County.	Table Mountain, Tuolumne County.	Corral Hollow, Alameda County.	South of Mount Diablo, Contra Costa County.	7½ miles southwest of Susanville, Lassen County.	Northend Mountain Meadows, Lassen County.	Moonlight, Lassen County.	Laramie.	Post-Laramie.	Fort Union.	Green River.	Eocene.	Miocene.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ficus shastensis Lesq			×?																×
Ficus tiliæfolia? Al. Braun	×	×												×	×				×
Ficus n. sp.		×																	
Gymnocladus n. sp.		×																	
Ilex prunifolia Lesq								×											
Juglans californica Lesq	×					×?													×
Juglans egregia Lesq	×	×				×													
Juglans laurinea Lesq	×																		
Juglans sp?		×																	
Juglans n. sp?													×						
Laurus californica Lesq		×			×	×			×		×		×					×?	×
Laurus furstenbergii Al. Br.									×										
Laurus grandis Lesq									×										×
Laurus princeps Lesq									×										
Laurus resurgens? Sap									×							×			
Laurus salicifolia Lesq									×		×								
Liquidambar californicum Lesq	×																		
Liquidambar, fruit of		×																	
Magnolia californica Lesq	×	×																	
Magnolia lanceolata Lesq	×	×				×					×					×		×	×
Magnolia n. sp.		×																	
Myrica ungeri Heer					×														×
Myrtus oregonensis Lesq									×										
Nyssa, fruit of		×																	
Persea dilleri Lesq			×?																×
Persea pseudo-carolinensis Lesq	×	×				×		×	×		×								
Persea punctulata Lesq						×			×										
Platanus appendiculata Lesq	×	×	×?										×						
Platanus dissecta Lesq					×			×	×	×									×
Populus balsamoides Göpp.									×									×?	×
Populus zaddachi Heer	×		×?			×					×		×			×	×	×?	×
Populus n. sp. cf. P. zaddachi		×																	
Pterospermites spectabilis Heer					×											×			×
Quercus boweniana Lesq		×		×									×						
Quercus castaneopsis? Lesq		×?																	
Quercus convexa Lesq		×						×					×						
Quercus distincta Lesq	×	×				×													
Quercus elænoides Lesq		×		×				×									×		
Quercus göpperti Lesq	×																		
Quercus nevadensis Lesq	×					×?													
Quercus olafseni Heer								×								×		×?	
Quercus pseudo-chrysophylla Lesq							×												
Quercus steenstrupiana? Heer							×												
Quercus transgressus Lesq							×												
Quercus voyana Lesq	×?																		
Quercus cf. Q. elænoides													×						
Quercus sp.													×						
Quercus n. sp.											×								
Quercus n. sp. (large leaf)											×								
Rhus boweniana Lesq		×						×?											
Rhus dispersa Lesq		×						×											
Rhus heufleri? Heer.									×										
Rhus metopioides Lesq						×		×					×						
Rhus mixta Lesq	×																		×
Rhus myricæfolia Lesq	×	×																	
Rhus typhinoides Lesq								×											
Sabalites californicus Lesq	×																		
Salix californica Lesq	×	×						×					×						
Salix elliptica Lesq	×?																		
Salix integra? Göpp.									×					×				×	
Salix varians Göpp.	×																	×?	×
Salvinia alleni Lesq		×															×		
Sequoia angustifolia Lesq									×								×	×	
Taxites olriki? Heer.									×							×			
Ulmus affinis Lesq	×?	×																	
Ulmus californica Lesq	×	×				×		×?											×?
Ulmus pseudo fulva Lesq	×	×				×							×						×
Ulmus, fruit of		×																	
Viburnum elongatum? Ward		×														×			
Viburnum tilioides? Ward		×														×			
Viburnum whymperi Heer		×														×?			×
Viburnum, fruit of		×																	
Viburnum n. sp.		×																	
Zanthoxylon diversifolium Lesq								×											
Zizyphus microphyllus Lesq	×																		
Zizyphus piperoides Lesq	×	×																	
Zizyphus n. sp.		×																	
	32	54	5?	3	7	12	5	18	19	5	8	1	13	2	3	13	6	11	22

According to the foregoing table there are at least 15 localities at which the auriferous gravels have been found to be plant bearing, the combined flora constituting an assemblage of 114 forms. The oldest or so-called deep gravels of Lindgren have not been found fossiliferous, the lowest apparent point at which plants occur being the upper portion of the bench gravels. To this horizon belong the localities of Chalk Bluffs, Nevada County (32 species); Independence Hill, Placer County (54 species); and Volcano Hill, Placer County (5 doubtfully determined species). The following localities with their respective floras are all intervolcanic: Monte Cristo mine, Spanish Peak, Plumas County (7 species); Mohawk Valley, Plumas County (12 species); Bowen's Tunnel, Placer County (3 species); near Forest City, Sierra County (5 species); Table Mountain, Tuolumne County (18 species); Corral Hollow, Alameda County (19 species); and south of Mount Diablo, Contra Costa County (5 species). According to J. S. Diller it is not possible to recognize in the auriferous-gravel area of Lassen County the horizons defined by Lindgren in the areas to the south, because the orogenic movements and subsequent denudation and covering have been so great as to effectively conceal the conditions. The three localities in Lassen County have yielded floras as follows: North end of Mountain Meadows (1 species); 7½ miles southwest of Susanville (8 species); and near Moonlight (13 species).

On referring again to the table it appears that of the 114 species constituting this flora, 35 species, or about 31 per cent, are found beyond the limits of the auriferous-gravel area. Of these 35 species 2 have been found in the Laramie, 3 in the post-Laramie, 13 in the Fort Union, 6 in the Green River formation, 11 in the Eocene of various places, and 22 in the Miocene. It is on these species, taken in conjunction with the obvious affinities of the endemic forms, that we must depend in determining the bearing of the plants on the age of the beds.

In the first volume of the "Geological Survey of California" J. D. Whitney considered the age of the auriferous gravels, and from the presence of bones of mastodon, elephant, rhinoceros, horse, camel, etc., as well as their apparent association with man-made implements, he concluded that they must belong to the Pliocene. J. S. Newberry, to whom was submitted plants from the Table Mountain locality, stated as his opinion that the beds "were not older than the Miocene." Leo Lesquereux, who next passed upon the fossil plants, stated that while a number showed evident affinity with the Miocene, and some even with the Upper Cretaceous, he concluded that the age should probably be regarded as lowest Pliocene or uppermost Miocene. Lesquereux was doubtless largely influenced in this view by the fact that a considerable number of the species studied by him showed undoubted affinity with species now living on the Atlantic slope. But since the time Lesquereux first wrote on the subject (1878) the known flora of the auriferous gravels has been considerably more than doubled, and, indeed, when he came to study later collections from Corral Hollow, the Monte Cristo mine on Spanish Peak, and Shasta County, he unhesitatingly placed them in the Miocene. My own rather desultory studies of this flora, which, however, included the rich deposits of Independence Hill, inclined me to regard it as clearly Miocene, a view which I still hold. On stratigraphic and physiographic grounds the conviction appears to have been growing of late that the auriferous-gravel period was a long one, possibly beginning as early as the Eocene, and if the plants obtained by J. S. Diller from the lower beds south of Susanville are really to be considered as belonging to the auriferous gravels this view is undoubtedly well founded, for these plants are clearly Eocene. But, as already pointed out, the matrix of the Susanville forms is entirely different from that carrying plants at all other localities, and I think it has yet to be demonstrated that this horizon is not lower and older than the true auriferous gravels.

Thus far no fossiliferous marine beds have been found in association with the plants within the area of the auriferous gravels, but in the Roseburg, Coos Bay, and Riddles quadrangles of southwestern Oregon Diller[1] has found plants apparently in the same beds with marine shells

[1] Proc. Washington Acad. Sci., vol. 8, 1907, p. 405.

that have been determined by W. H. Dall to be of undoubted Eocene age. The plant material was very poorly preserved, but from it I was able to make the following provisional identifications:

Magnolia lanceolata Lesq.	Populus zaddachi Heer.
Magnolia californica? Lesq.	Aralia angustiloba? Lesq.
Laurus californica? Lesq.	Juglans californica? Lesq.
Sabalites californicus? Lesq.	Ulmus californica Lesq.
Aralia whitneyi Lesq.	Ficus tiliæfolia Al. Braun.

It needs but a glance to show that this list is typically that of the auriferous-gravel flora, but unfortunately, as stated above, the material is so poorly preserved that all but three of the identifications are much in doubt. The three species, which are positively identified, are *Magnolia lanceolata*, *Aralia whitneyi*, and *Ulmus californica*. On referring to the table it appears that two of these species (*Magnolia lanceolata* and *Aralia whitneyi*) are among those found outside of the auriferous gravels, at horizons which take them well down into the acknowledged Eocene. They have both been reported from the Fort Union formation as well as from the Ione formation of Shasta County, Cal., and other localities—a fact which undoubtedly robs them of the significance they might otherwise have as tending to prove the Eocene age of all the auriferous gravels. It is not to be denied, however, that an analysis of the table of distribution shows that a fair percentage of the 35 species having an outside range occur at horizons below the Miocene, but on the other hand there are 22 species (about 60 per cent) which are found in or confined to the Miocene.

Thus far the obvious affinity of the endemic species of this flora has not been considered, and lack of space prevents a complete analysis of this kind here, but I do not hesitate to state that in broad terms this affinity is beyond question with the Miocene. In conclusion, therefore, I feel myself justified in holding to the opinion that the flora of the auriferous gravels is of Miocene age.

CHAPTER 4. GOLD OF THE TERTIARY GRAVELS.

GEOGRAPHIC DISTRIBUTION.

The occurrence of gold in paying quantities in the Tertiary gravels of the Sierra Nevada is limited almost entirely to the gravels in which quartz and metamorphic rocks form the principal components. This is natural because the gold is derived wholly from veins occurring in the metamorphic rocks of the range. In places gold-bearing deposits of primary character are also found in granitic rocks adjacent to the metamorphic area, but these granitic rocks rarely furnish material for pebbles and cobbles on account of their rapid disintegration. A little fine or flour gold is found in the sands and clays which cover the gravels. Gravel beds embedded in the volcanic series and consisting chiefly of andesitic pebbles contain gold only when during their deposition adjacent beds of older gravels or parts of the "Bed-rock series" happened to be exposed to erosion. The Tertiary rocks of the western slope of the range, almost without exception, are barren of precious-metal deposits.

The distribution of detrital gold is strictly dependent on the distribution of primary deposits in the pre-Tertiary rocks of the range. These are confined almost exclusively to the Paleozoic and Mesozoic sedimentary rocks and to the igneous rocks which are associated with them and which were erupted and metamorphosed before the principal intrusion of the great granitic masses of the Sierra took place. The primary gold deposits were formed shortly after these granitic intrusions. It is a remarkable fact that the large areas of granite in the Sierra are almost wholly barren except close to the contact with the metamorphic series, where smaller veins may begin to appear. About the same time as the main intrusion minor masses of granitic and dioritic rocks were forced into the adjacent older series. In and surrounding these smaller intrusions gold-bearing deposits are particularly abundant. In their distribution the gold-bearing gravels reflect these conditions in a most accurate manner. The Tertiary and recent rivers traversing the large granite area of the upper part of the range are in general entirely barren, but after entering the metamorphic areas they speedily become charged with auriferous detritus. The amount of gold contained in the streams changes within short distances. Adjacent to the main granite contact, in Eldorado, Amador, and Calaveras counties, are considerable areas of the Calaveras formation—monotonous clay slates or siliceous slates without many areas of igneous rocks. Here the Tertiary channels are poor as a rule, but lower down they become greatly enriched on reaching the areas in which sedimentary and igneous rocks are intimately mingled.

In Sierra, Yuba, and Butte counties the Tertiary channels are rich in gold almost up to the divide of the range, the conditions corresponding to those outlined above. In Nevada County they are barren in the extreme eastern part, but soon after entering the metamorphic area they become greatly enriched, first by the Washington belt of quartz veins and second after crossing the long complex dike known as the Serpentine belt. In Placer County the channels are almost barren in the eastern part but become tremendously enriched in crossing the continuation of the Washington belt of quartz veins, here appearing in the vicinity of the Hidden Treasure mine. The Serpentine belt is crossed near Forest Hill and here the result is again a great enrichment. In Eldorado County the upper channels to points within a few miles of Placerville are generally poor, but at those points, where they cross the Mother Lode, coarse gold appears in enormous quantities and the enrichment continues for a considerable distance below this line. In the counties farther south similar conditions prevail. Wherever the channels cross areas rich in gold-bearing quartz veins they become heavily charged with gold. Above such deposits the channels grow rapidly poorer; below them the decrease in tenor is gradual. In Amador, Calaveras, and Tuolumne counties it so happens that most of the ancient river deposits below

the great Mother Lode are either eroded or so heavily covered that they can not be mined. This great source of enrichment being absent, the general grade of the gravels in these counties is lower than in those farther north. In Tuolumne County, just previous to the Table Mountain flow, a drainage channel was established for a short time across the Mother Lode and this water-course, covered by a basaltic flow of great resistance, has escaped subsequent erosion. The gravels deposited in it have been mined underneath the Table Mountain west of the Mother Lode. They were rich in places, but the channel existed for too short a time to become heavily enriched. Smaller patches of gravel preserved in the same position west of the Mother Lode, as near Chinese Camp, have proved very rich. South of Tuolumne County few Tertiary gravels have been preserved from erosion.

The geographic relations sketched above in merest outline prove conclusively the dependence of the gravels for their enrichment on the distribution of the primary vein deposits, and it may be safely asserted that the gold in the channels is almost exclusively derived from such deposits.

DISTRIBUTION OF THE GOLD IN THE GRAVELS.

It has become almost an axiom among miners that the gold is concentrated on the bedrock and all efforts in placer mining are generally directed toward finding the bedrock in order to pursue mining operations there. It is well known to all drift miners, however, that the gold is not equally distributed on the bedrock in the channels. The richest part forms a streak of irregular width referred to in the English colonies as the "run of gold" and in the United States as the "pay streak" or "pay lead." This does not always occupy the deepest depression in the channel and sometimes winds irregularly from one side to the other. It often happens that the values rapidly diminish at the outside of the pay lead, but again the transition to poorer gravel may be very gradual. An exact explanation of the eccentricities of the pay lead may be very difficult to furnish. Its course depends evidently on the prevailing conditions as to velocity of current and quantity of material at the time of concentration. The gravel outside of the "pay streak" would ordinarily be regarded as extremely rich by the hydraulic miner, who would be content with a yield of 10 cents a cubic yard; but the drift miner is obliged to leave as unpayable gravel containing from 75 cents to $2 a cubic yard. Figure 12 (p. 151) illustrates the position of the pay lead in the Mayflower channel, according to Ross E. Browne.

SIZE OF THE GOLD.

Although the larger part of the gold in the channels is fine or moderately fine, large nuggets are sometimes found and much speculation has been indulged in as to their origin. It has been repeatedly stated in the literature that large nuggets occur more commonly in the gravels than in the veins. It is difficult to trace the origin of this tradition; it certainly has little foundation in fact. The largest masses of gold found in California are said to be that from Carson Hill, which weighed 195 pounds troy, and that from the Monumental quartz mine, in Sierra County, which weighed about 100 pounds troy. The mass at Carson Hill, if not directly in a quartz vein, was at any rate immediately below the croppings and not in any well-defined alluvial channel. The well-known heavy nuggets obtained near Columbia, Tuolumne County, were found in a vicinity of rich pocket veins where decay of rocks has proceeded without much interference since Tertiary time, and in which assuredly there has been little transportation. Heavy masses of gold are exceedingly common in the so-called pocket veins of Sonora. Many of the veins near Alleghany and Minnesota, in Sierra County, contain remarkably heavy masses of gold. Hanks,[1] in his list of nuggets found in California, states that a slab of gold quartz extracted from the Rainbow mine, near the locality just mentioned, was calculated to contain gold to the value of $20,468. The total yield from a single pocket of this mine was $116,337.

The Ballarat nuggets, some of which weighed from 100 to 200 pounds, found near the town of Ballarat, in Victoria, Australia, are often quoted as conspicuous examples of masses of gold

[1] Hanks, H. G., Second Rept. State Mineralogist California, 1882, p. 49.

found in streams for which an explanation is difficult. It is true that these nuggets were recovered by mining channels underneath the basalt, but it is not ordinarily noted that these channels were simply small gullies or ravines heading a short distance from the place where they were mined and traversing the decomposed outcrops of an exceedingly rich system of gold-bearing quartz veins. Of the direct derivation of these nuggets from such veins by processes of erosion and rock decay there can be no doubt.

The gold in the larger channels of the Sierra Nevada is usually fine to medium fine. Grains of the size of wheat kernels are considered as being very coarse gold, and in most places the size of the average grain corresponds more nearly to that of a mustard seed. In form most of the grains are flattened, a natural result of the continual pounding of the particles by the cobbles in the moving gravel. A certain proportion of the gold is extremely fine, and this part constitutes the so-called flour gold, which may be so fine that one or two thousand particles must be obtained to get the value of a cent.

Few systematic investigations are available regarding the proportion of coarse and fine gold in the channels, and the various localities show indeed great divergence. The data given by Hanks [1] and Blake [2] regarding the occurrence of nuggets show that in the main channels large masses of gold are on the whole rare. Most of the masses noted are from gulches or minor streams close to croppings. Very coarse gold was found in the tributary channel extending from Minnesota to Forest. In the Live Yankee claim, at Forest, 12 nuggets were found weighing from 30 to 170 ounces. At Remington Hill and Lowell Hill, in Nevada County, both of which are on a tributary to the main river, pieces weighing from 58 to 186 ounces are recorded. The gold is rarely found in the quartz pebbles and bowlders of the channels; however, Blake records the discovery at the Polar Star mine of a white quartz bowlder which yielded gold to the value of $5,760. This is in the gravel of a principal tributary to the Tertiary Yuba River, at a point where the contact of slates with the "Serpentine belt" is crossed. The White channel, mined by the Hidden Treasure mine, contains rather unusually coarse gold. It is a broad gravel deposit, 800 feet wide in places, accumulated on a tributary to the main river descending by way of Long Canyon, Michigan Bluff, and Forest Hill. The coarse gold is explained by the fact that the stream followed a belt of clay slate rich in auriferous quartz veins. Some of the gold occurs in rounded grains, many of which have pitted surfaces, but most of the pieces are flat. Small nuggets of a value of 10 to 50 cents are common, and larger pieces worth from $10 to $400 are occasionally encountered. At the celebrated Morning Star and Big Dipper drift mines, at Iowa Hill, the gold is also decidedly coarse, some pieces of a value up to $20 being found, but at other places along the same main branch of the Tertiary Yuba River much finer gold prevails, and a small part of it, which is difficult to recover, can even be classed as flour gold. Blake states that in the deep channels at You Bet, in Placer County, the gravel is in some places literally packed with small scale gold. He found that in a sample from American River the scales averaged less than 1 millimeter in diameter. The thickness is usually from one-third to one-fifth of the diameter.

Hoffman [3] has furnished a valuable description of the Red Point channel, which forms a tributary or upper extension of the White channel, on the Forest Hill divide. The gold obtained in this drift mine was classified by him as follows: Coarse, 15.78 per cent; medium, 48 per cent; fine, 36 per cent; powder, 0.32 per cent. Coarse gold is defined as that which will not pass a sieve of 10 meshes to the inch. Medium gold is defined as that which will not pass a 20-mesh sieve; this is more scaly and uniform in size, averaging 2,200 colors to the ounce. Fine gold is defined as that which will not pass a 40-mesh sieve; this averages 12,000 colors to the ounce. The remaining part, or powder, passed through a 40-mesh sieve and averages 40,000 colors or more to the ounce.

On the whole, it may be said that flour gold, such as is found in the beaches of the California and Oregon coasts or in the sands of Snake River, is not abundant in the Tertiary

[1] Hanks, H. G., Second Rept. State Mineralogist California, 1882, pp. 148-150.
[2] Blake, W. P., The various forms in which gold occurs in nature: Repts. Dir. Mint on Precious Metals, 1885, pp. 573-597.
[3] Hoffman, C. F., The Red Point drift gravel mines: Trans. Tech. Soc. Pacific Coast, vol. 10, No. 12, 1894, pp. 291-307.

or present gravels of the Sierra Nevada. During both Tertiary and present time the grades of the rivers have been such as to prevent its accumulation, and the largest part of such material has undoubtedly been swept out among the sediments which now fill the Great Valley of California.

RELATIVE VALUE OF QUARTZ GOLD AND PLACER GOLD.

Observations in all parts of the world have shown that placer gold is always finer than the gold in the quartz veins from which the placers were derived. The explanation, as has been shown in a most convincing manner by Ross E. Browne,[1] among others, is that the silver alloyed with the gold is dissolved by the action of surface waters. The purity of the gold becomes greater as the size of the grains diminishes, the explanation being, of course, that the proportionate amount of surface exposed to the action of solutions is greater in the finer gold. An interesting confirmation of this view is recorded by McConnell,[2] who states that examination of nuggets from the Klondike shows that their surfaces consist of gold of greater fineness than their insides. Some interesting data on the fineness of California gold have been contributed by F. A. Leach and C. G. Yale.[3] A few of these data, which were obtained from mint returns for a period embracing several months of 1898, are mentioned below. The average fineness of the gold of Nevada County is given as 855; of Placer County, 792; of Plumas County, 851; of Sierra County, 858; of Calaveras County, 835; of Tuolumne County, 804. This includes both placers and quartz mines. The finest gold produced in California is that from the San Giuseppe quartz mine, near Sonora, Tuolumne County. This gold runs from 982 to 998, or $20.63 an ounce. On the whole, however, the gold from quartz veins is decidedly lower in grade than that from placers. The highest average of fineness in California is that of the gold from the placers at Folsom, Sacramento County, which runs from 974 to 978. The gold from the dredging areas of Butte County, near Oroville, is also of high grade, averaging about 922. At the localities cited the gold is obtained mainly from Quaternary deposits in the present rivers.

In Plumas County the listings of quartz gold run from 627 to about 850 and the placer gold from 800 to 950.

In Sierra County gold from quartz mines varies from 622 to 883; gold from the hydraulic mines at Port Wine (a Tertiary channel) is 948 in fineness. At Gibsonville similar deposits show a fineness of about 900.

In Nevada County the quartz veins produce gold ranging from 645 to 890. The Tertiary gravels of the Harmony channel show the lowest grade of placer gold; it is 790 fine, but is derived from a small channel immediately crossing a number of rich veins so as to offer little chance of enrichment. In the main channel, at the Manzanita mine, at Nevada City, the fineness is 830. Gold from the deep channels of North Bloomfield and Relief has a fineness of 906 to 935; at the Alpha hydraulic mine, 940 to 950; at American Hill and French Corral, all in main channels, 930 to 950.

In Placer County the quartz veins carry gold of a fineness from 580 to 921. In the main channels of Tertiary gravels may be noted the Morning Star mine, at Iowa Hill, where the gold is 900 fine; the Big Dipper, on the same channel, 884; Michigan Bluff, 940 to 970; the Red Point drift mine, 927; and the Hidden Treasure mine, on the White channel, 924 to 941.

In Eldorado County the quartz gold varies from 570 to 901 in fineness. At the Excelsior claim, at Placerville, on one of the principal channels, the gold on the bedrock had a fineness of 925, while that in an upper stratum at the same place, on "false bedrock," reached 975. The gold in the Snow mine, above Placerville, a gravel deposit in the main Tertiary river, runs 948 fine. A drift mine at Grizzly Flat, on a small Tertiary stream near the headwaters and near some quartz veins, runs 871 fine.

In Calaveras County the quartz veins yielded gold ranging in fineness from 627 to 885; one exceptional quartz mine near Angels Camp shows a fineness of 960 to 975. The gold in the

[1] California placer gold: Eng. and Min. Jour., vol. 59, 1905, pp. 101-102.

[2] McConnell, R. G., Report on gold values in the Klondike high-level gravels. Geol. Survey Canada (pub. No. 979), 1907, p. 14.

[3] California mines and minerals, San Francisco, 1899, pp. 175-187. See also Bowie, A. J., jr., Hydraulic mining in California, 1885, p. 289; Hittell, J. S., Fourth Ann. Rept. State Mineralogist California, pp. 219-223.

gravels of the main Tertiary river draining this county yielded at Vallecito gold from 940 to 987 fine. In the Green Mountain hydraulic mine, at Mokelumne Hill, the fineness was 919.

The figures quoted show very clearly that in the main Tertiary streams a considerable refining of the gold has been going on, so that the average grade is now decidedly above 900. It is difficult to compare accurately the tenor of the gold in the present streams with that in the Tertiary channels, for it must be remembered that the former contain a mixture of detrital gold derived from Tertiary channels with much new gold set free during the erosion of the present canyon system.

DEPOSITION OF PLACER GOLD FROM SOLUTIONS.

In spite of the fact that the geologic conditions indicate so clearly a direct derivation of the gold from quartz veins, there have always been a number of adherents of the view that placer gold is formed by chemical deposition in the gravels. This view was held extensively among the Australian geologists of earlier years and was also earnestly advocated by Prof. Egleston, of Columbia University, New York. In recent years A. Liversidge[1] has made an extensive examination of nuggets from various sources in order to ascertain whether they bear any evidence of segregation in water. He concludes that they are derived entirely and directly from veins and that "any small addition they may have derived from meteoric water" is quite immaterial and may be neglected. Only in two nuggets from New Guinea were concentric lines of accretion observed. All other nuggets examined on etching developed signs of crystalline structure such as is entirely natural to find in vein gold. Maclaren[2] regards this structure as an argument in favor of growth in place, but it is difficult to understand his reason for this opinion.

The long exposure during gradual accumulation and the long rest of the gravels in channels exposed to percolation of atmospheric waters since Tertiary time has evidently produced a great enrichment in the fineness of the gold. The average grade in the main Tertiary channels is clearly much over 900. The highest grades of the fine-sized gold in Quaternary deposits where the canyons open into the valley are from 922 to 978. In this connection it is interesting to recall the statement by C. F. Hoffmann that the gold in the Red Point channel was of the highest grade wherever the gravels appeared to be particularly exposed to the percolation of water.

It is a well-known fact that solutions containing ferric chloride have the power to dissolve metallic gold to some extent and it is believed that in most places where solution and precipitation can be proved such solutions have been active. It was thought for a long time that ferric sulphate had the same property, but the investigations of Stokes[3] indicate that this is the case only where ferric chloride is also present. Pearce, Rickard, and lately W. H. Emmons[4] have shown that nascent chlorine is the really important agent in the solution of gold, while ferrous sulphate probably is the main precipitating agent. The action of manganese dioxide on acid solutions of sodium chloride would produce the necessary nascent chlorine. Undoubtedly some such action has taken place in the gravels of the Sierra, but there is little evidence that it is quantitatively important. The circulating waters are of great purity and probably contain extremely little sodium chloride and free acid. The gravels contain little recognizable manganese.

The evidence of secondary precipitation of gold in the California gravels is exceedingly meager and appears to be confined to two modes of occurrence. As noted above, pyrite and marcasite deposited in the gravels are in some places auriferous, though they have not been found to contain large amounts of the precious metals and there is usually difficulty in proving that no detrital gold was included. The second mode of occurrence consists in the deposition of gold on particles of magnetite or ilmenite associated with the gold. Microscopic preparations clearly showing that such a deposition had taken place were shown to the writer by Mr. J. A. Edman, of Meadow Valley, who has made a special study of the black sands of California. The particles referred to came from the Tertiary gravels of Providence Hill, in Plumas County, and the black grains are partly covered with a thin crust of gold. Mr. Edman admits that

[1] Jour. Roy. Soc. New South Wales, vol. 40, 1906, p. 161.
[2] Maclaren, J. M., Gold, London, 1908, p. 83.
[3] Stokes, H. N., Experiments on the solution, transportation, and deposition of copper, silver, and gold: Econ. Geology, vol. 1, 1906, p. 650.
[4] Bull. Am. Inst. Min. Eng., No. 46, October, 1910.

such occurrences are very rare. Several instances of the occurrence of precipitated gold in the roots of grasses near the surface and also in compact clays have been noted in the literature. Maclaren [1] cites an occurrence of this kind in the crystallized gold of Kanowna, Western Australia, where tiny yet bright and sharply defined octahedral crystals occur in the so-called "pug" or ancient clay gravel. McConnell [2] cites from the Klondike a quartz pebble carrying numerous thin specks and scales of crystallized gold dendritically arranged. Maclaren in the place referred to lays much emphasis on the occurrence of crystallized gold from alluvial mines. Such occurrences are certainly extremely rare in California. A number of specimens of this kind were found at Byrds Valley, near Michigan Bluff, in Placer County, but they were very near their source in local pocket veins and were partly rounded. The writer believes it very improbable that large crystals of gold have ever been formed under the conditions prevailing in the Tertiary gravels of California.

In all placer mines it is exceedingly common to find that the gold works downward into the softened bedrock immediately underlying the gravel and places are known where it has descended to a depth of 2 or 3 feet. On limestone bedrock extremely deep and irregular cavities of dissolution are often formed, and in these placer gold may be carried down to depths of 30 or 40 feet or even more; this was frequently observed in the rich placers of Columbia, Tuolumne County (Pl. XI, *A*, p. 72). In a recent textbook on mining geology this gold which is mechanically admixed with the bedrock is asserted to be due to chemical precipitation. The phenomenon and its true explanation are perfectly well known to every practical placer miner. At all drift mines the bedrock is removed to a depth of at least a foot below the gravel and washed with that in subsequent operations.

So far as the Tertiary gravels of California are concerned, the conclusion of the writer is that solution and precipitation of gold have played an absolutely insignificant part.

TENOR OF THE GRAVELS.

The productiveness of a channel is best measured by its yield per linear foot. A distinction must of course be made as to whether the hydraulic method is employed and thus the whole amount of gravel is washed or whether only the rich bottom layer is mined by drifting. In general it may be said that the channels yield from $70 to $500 to the linear foot; in drifting operations rarely more than half of the total amount of gold contained in the gravel is obtained, for besides the inaccessible gold in the upper gravels there are usually considerable bodies of gravel on the bedrock of too poor a grade to pay for extraction.

Pettee [3] mentions the instance of American Hill, near San Juan, in Nevada County, which was mined by the hydraulic method many years ago. The mass was 3,000 feet long, 1,000 feet wide, and approximately 150 feet high; it yielded $1,241,000, equivalent to $414 a running foot. Among channels mined by drifting the gravels at Red Point described by Hoffmann averaged 200 feet in width and yielded for a distance of somewhat over a mile at the rate of $71.65 a foot.

The Mayflower channel, also in Placer County, in which the average width of breasted gravel was 75 feet, yielded for 3,900 feet at the rate of $150 a foot, according to Ross E. Browne.[4] The Paragon channel, which is the upper continuation of the Mayflower, yielded $125 a running foot. In the same mine an upper channel 225 feet wide on tuff bedrock produced $300 a foot. At the Hidden Treasure mine the width of pay gravel averaged for a long time 250 feet and the average yield was $150 a running foot. The Ruby Gravel mine, in Sierra County, in which the channel was from 50 to 300 feet in width, was worked for a distance of 3,850 feet and yielded at the rate of $465 a linear foot. The cost is stated to have averaged $240 a foot. A number of data regarding the yield of gravels in drift and hydraulic mines are found in the reports of the State mineralogist of California.[5]

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[1] Maclaren, J. M., Gold, London, 1908, p. 83.

[2] McConnell, R. G., Ann. Rept. Geol. Survey Canada, vol. 14, 1901, p. 64B.

[3] Report by J. D. Hague in Whitney, J. D., Auriferous gravels, 1879, p. 206.

[4] Tenth Ann. Rept. State Mineralogist, 1890, pp. 435–466.

[5] See especially Hammond, J. H., The auriferous gravels of California: Ninth Ann. Rept. State Mineralogist, 1890, pp. 105-138; Browne, R. E., The ancient river beds of the Forest Hill divide: Tenth Ann. Rept. State Mineralogist, 1890, pp. 435–466.

For comparison it may be mentioned that according to A. H. Brooks the average value of the principal creeks at Nome, Alaska, is approximately $100 a foot. The White channel in the Klondike yielded $380 a foot. In the Berry drift mines in Victoria, Australia, the yield per foot ranged from $440 to $1,293, the width of gravel mined being from 330 to 1,000 feet.

The amount of gold contained in the gravels is usually measured by the cubic yard of gravel, more rarely by the ton or the "carload." The latter is, of course, an indefinite quantity, but usually about equivalent to or a little less than 1 ton. One ton of broken gravel is assumed to contain about 18 cubic feet.

The gold content of the gravel varies, of course, enormously. In general it may be said that the upper gravels, sands, and clays are very poor; and although more gold is contained in the lower gravels it is only within a few feet of the bedrock that the rich material begins to appear. By far the greatest part of the gold is ordinarily contained in the gravel within 3 feet of the bedrock, and in many places within the last foot above the bedrock. In drifting operations only a few feet of gravel above bedrock are extracted; in many hydraulic operations the whole mass is washed, including parts of the almost barren overburden of fine gravels, sand, clay, or rhyolitic tuff. Wherever possible the overlying andesitic breccia is excluded from the bank wash, for besides being barren the tenacious masses of this material are difficult to handle.

Though it is difficult to give exact figures, it may be said that within the productive region the hydraulic washing of deep banks varying perhaps from 50 to 300 feet in height yielded, including the top and bottom gravels, between 10 and 40 cents a cubic yard. The top gravels alone will vary between 2 and 10 cents a cubic yard and the drifting ground on the bedrock from 50 cents to $15 or more.

In the following paragraphs a few data regarding the grade of the gravels are assembled from the detailed descriptions in Part II of this report.

At Morris Ravine, near Oroville, the best drifted ground yielded from $4 to $9 a cubic yard; this is a minor channel. A main branch of the Tertiary Yuba River at Poverty Hill, Sierra County, yields $2 a cubic yard within 5 or 6 feet from bedrock; the lower 2 feet contains most of the gold, but much is also derived from the upper part of the section. At La Porte, Plumas County, the deep gravels yielded from $2 to $20 a cubic yard. According to W. H. Pettee, one bank of gravel, covering an area of 250 by 100 feet and 30 feet high, yielded at the rate of $21 a ton. Most of the gold is said to be within 2 feet of the bedrock. At North Bloomfield, Nevada County, the gravels average between 200 and 300 feet in depth. The upper 120 feet of fine gravel contains small values but a considerable number of pieces of scaly gold of little value or weight. The lower 87 feet contains most of the gold, and the last 8 feet above the bedrock yields high values, averaging about $1.50 a ton. A large amount of the upper gravel at North Bloomfield, washed from 1870 to 1874, yielded, according to A. J. Bowie, jr.,[1] 2.9 cents a cubic yard. This work afforded practically no profits. In 1877 the bottom gravel, 65 feet deep, was found to yield 32.9 cents a cubic yard, but the top gravel, which was up to 200 feet deep, yielded only 3.8 cents. The Derbec drift mine, near North Bloomfield, working on a branch of the same channel, mined gravel from which $2.47 a ton was recovered.

The thick gravels between Dutch Flat and Indiana Hill are stated to yield 11 cents a cubic yard; the cemented gravel on the bedrock at Indiana Hill contained up to $9 a yard.

Rich hydraulic ground was found in the gravel areas extending from North San Juan, in Nevada County, to Smartsville, in Yuba County; large masses of them, with banks up to 150 feet in height, are said to have yielded from 30 to 37 cents a cubic yard. Between Cherokee and North Columbia, below North Bloomfield, in Nevada County, the gravels are up to 600 feet in thickness and very extensive; these top gravels are said to contain from 10 to 15 cents a cubic yard. At Omega, Nevada County, where the hydraulic banks reach 150 feet in height, the yield is said to be 13½ cents. At Blue Tent, Nevada County, the upper gravels and sands are practically barren, but the lower gravels are said to contain 15 cents a cubic yard. At this place the channel is 1,000 feet wide, and 5 feet of gravel next to the bedrock is stated to contain 50 cents a ton.

[1] Hydraulic mining in California, 1885, p. 74.

The Forest Hill divide, in Placer County, is particularly rich in drift mines. South of Iowa Hill the Morning Star and Big Dipper drift mines worked the main channel for a length of 10,000 feet. From 6 to 7 feet of gravel was extracted, and the contents ranged from $10 to $14 a cubic yard; gravel containing less than $2 was not considered payable. At the Dardanelles mine, at Forest Hill, the channel was 75 feet wide, and gravel to the depth of 5 feet was extracted; in one part of the mine gravel was extracted in floors to the height of 38 feet.[1] A number of smaller channels at Forest Hill were extremely rich. Pettee mentions a piece of ground on the New Jersey claim, 800 by 300 feet, from which $1,500,000 is believed to have been taken by drifting.

The Mayflower channel was mined for a distance of 3 miles and had an average width of 75 feet. A thickness of 2 to 14 feet of gravel was extracted and is said to have yielded $7 a ton; 66 per cent of the bottom gravel was found to pay for mining. At the Paragon mine, where the same channel was mined, an upper lead, 150 feet above bedrock, was discovered. The false bedrock consisted of rhyolite tuff; the channel was 225 feet wide and the lower 5 feet of gravel is said to have yielded $4.50 a ton.

The Hidden Treasure, northeast of Forest Hill, has worked for more than 8,000 feet a channel containing loose quartz gravel and ranging in width from 250 to 800 feet; from 4 to 7 feet of gravel is extracted, together with 1 foot of decomposed bedrock, and the yield is stated to range up to $1.75 a ton; at this mine the costs are unusually low.

Rich gravels were also mined near Placerville. At the Excelsior claim a considerable mass of gravel 100 feet in thickness is stated on reliable authority to have averaged $1 a cubic yard, worked by the hydraulic method. At this place two upper pay streaks occurred, one 25 feet and the other 60 feet above the bedrock. The deep gravel of the so-called Blue lead at Placerville, averaging about 100 feet in width, yielded cemented gravel containing from $2 to $3.50 a cubic yard. From Smiths Flat to White Rock many rich benches produced gravel containing as much as $19 a carload, which is somewhat less than a ton.

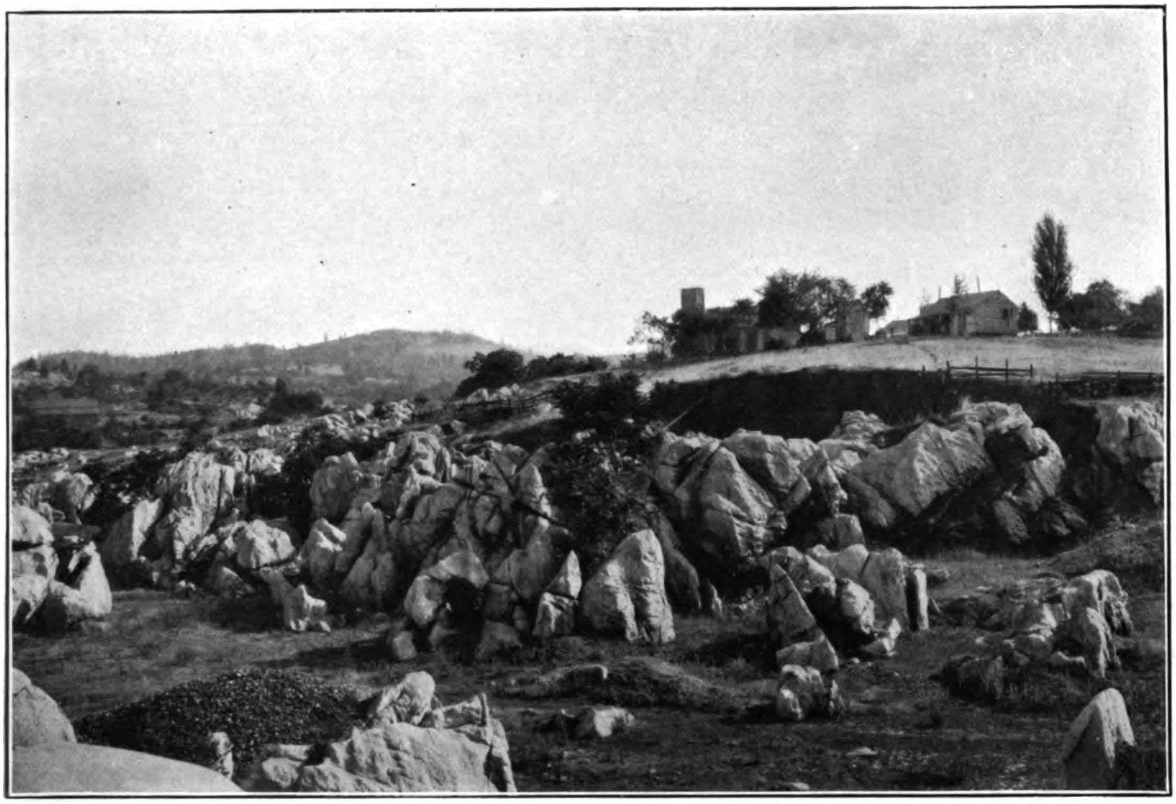
In Calaveras County the gravels are ordinarily of somewhat lower grade, although, of course, many rich localities were found. The gravel in the Deep Blue lead of Mokelumne Hill, at the North Star mine, is said to average $1.95 a ton in drifting operations. At the Banner drift mine, on the Fort Mountain channel, the bottom gravel is said to contain $3 a ton, and the costs of mining and milling are given as $1 to $1.25 a ton.

THE BEDROCK.

The bedrock of the Tertiary channels may, of course, consist of any of the great variety of rocks of Jurassic or earlier age which make up the Sierra Nevada. The channels occupy flat trough-shaped depressions in these rocks; the form of one of the larger channels is well illustrated by Plate V, *B* (p. 30), showing the Dardanelles mine in Placer County, the bottom of the channel being laid wholly bare by hydraulic work. On either side of the channel the rising rims may flatten into smaller benches. The bottom is, like any river channel of to-day, of irregular form, ridges alternating with depressions or potholes. The general trough shape is likely to be broken by a deeper gutter of varying width, but this feature is not always present. The ups and downs of such an old river bottom are well illustrated in figure 12 (p. 151), showing the bedrock of the Mayflower channel of the Forest Hill divide.

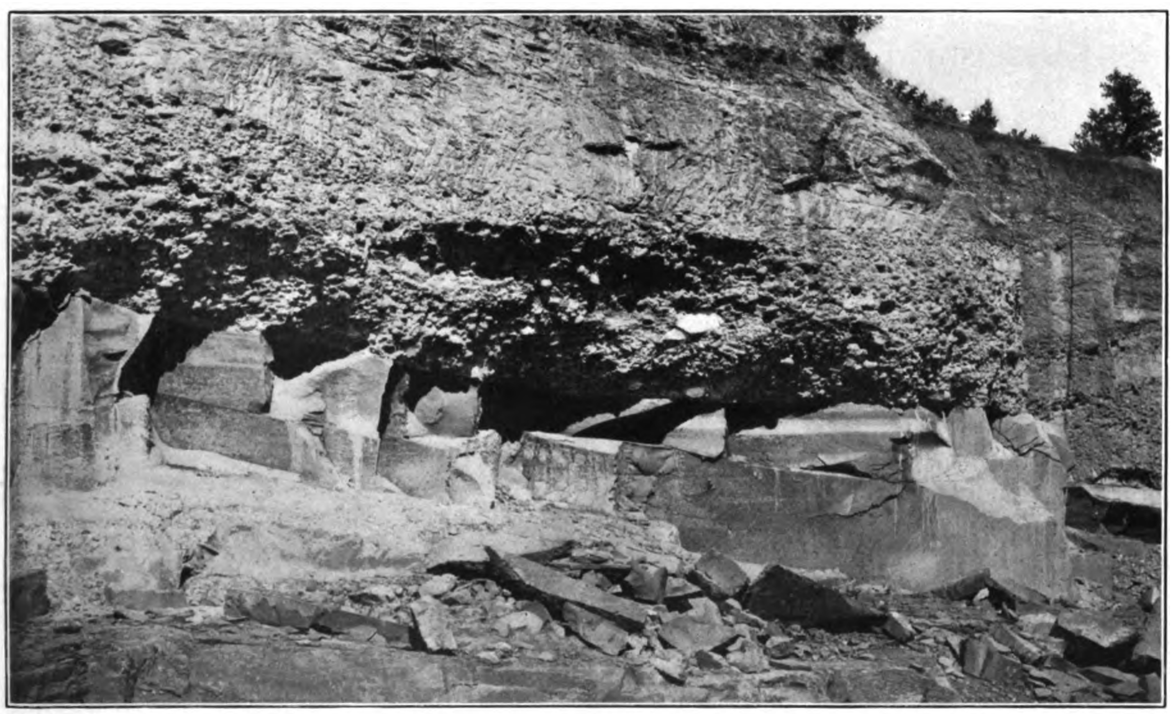
The surface of the bedrock is usually hard, contrasting strongly in this respect with the soft and clayey slate bedrock found in the drift mines of Victoria, Australia. In some places, however, as in the slates of the Hidden Treasure mine, the bedrock has been greatly softened and bleached so that there is no difficulty in removing it with the pick. In the few places where the gravels rest on granitic bedrock the bedrock is greatly softened and usually possesses the disagreeable quality of swelling. This was particularly well illustrated in the mines on the Harmony channel, near Nevada City, where the swelling took place so rapidly that drifts not attended to would be closed within a few months.

[1] Browne, R. E., Tenth Ann. Rept. State Mineralogist of California, 1892, p. 447.



A. LIMESTONE AT COLUMBIA, TUOLUMNE COUNTY.

Sculptured by erosion and exposed by placer mining. Photograph by G. K. Gilbert. See page 213.



B. UNCONFORMITY OF NEOCENE SHORE GRAVEL ON SANDSTONE OF IONE FORMATION, JACKSON QUADRANGLE.

Photograph by H. W. Turner. See page 197.

In limestone areas the bedrock is extremely irregular (Pl. XI, *A*) and solution has produced holes which in places may be 50 or 75 feet in depth. Accumulation of rich gravels often takes place in these cavities.

A soft bedrock is considered advantageous because of its property of catching the gold driven across its surface in the moving gravels. Sometimes the gold will work down into the soft mass for a depth of 1 to 2 feet. On the other hand, a hard and smooth bedrock is less efficacious as a gold catcher, and serpentine is said to be especially unfavorable in this respect. The steeply dipping ridges made by alternate strata of slate serve to catch the gold, but at many places it is held to be more advantageous if the strike of the slates runs parallel to the channel than if they cross it.

In many parts of the United States gold-bearing gravels rest on clays or tuffs above the true bedrock, and this means, as a rule, several epochs of gold concentration. In the Tertiary rivers of California such secondary pay streaks and false bedrock are of comparatively rare occurrence. Gold is not retained on the surface of sand and gravel, and during the deposition of the gold-bearing gravels proper such thick clay beds were not ordinarily formed on account of the generally steep grade of the watercourses in a region of accentuated topography. Later, during the epoch of the rhyolitic eruption, such tuffs and clays were frequently deposited, but at that time there was little opportunity for the accumulation and concentration of gold in the wide flood plains. Some notable occurrences of false bedrock are mentioned in the detailed descriptions. An excellent example is that of the upper channel 150 feet above bedrock between Mayflower and Bath, on the Forest Hill divide. This channel was 225 feet wide and 5 feet deep and yielded $4.50 a ton. The lower channel, only 75 feet wide, was richer, averaging in the drifting ground $7 a ton. Another excellent example is found in the three pay streaks of the Excelsior mine near Placerville, which has been mentioned above.

MINERALS ACCOMPANYING GOLD IN THE TERTIARY GRAVELS.

Comparatively few useful minerals are found with the gold in the Tertiary gravels, but naturally the concentration which sorted out the gold from the bedrock also accumulated in the sands and gravels such heavy minerals as may be contained in the rocks. In the sluice boxes which are used for the washing of gravels these heavy minerals accumulate, and from the prevalence among them of magnetite and ilmenite they are usually referred to as "black sands."

The minerals occurring in the gravels may be divided into those of detrital origin and those which have been formed by chemical action within the gravels themselves.

DETRITAL MINERALS.

As stated above, magnetite and ilmenite are the most common of the minerals which accompany the gold, and their derivation is easily found in the basic rocks, like diabase, gabbro, and allied greenstones, which occupy so much space in the gold-bearing region. The granodiorites also furnish a considerable amount of magnetite. Most of the ilmenite is doubtless derived from the basic rocks mentioned. The Tertiary volcanic rocks are also rich in these constituents and channels traversing them are likely to contain an exceptional amount of black sand. A number of detailed determinations of the quantity of these minerals present were made in the examination of the black sands by D. T. Day at Portland in 1905,[1] and the mineralogical classification was carried out by Charles H. Warren, of the Massachusetts Institute of Technology. From the results it appears that magnetite largely prevails, but that chromite is also present in considerable quantity, as was indeed to be expected from the occurrence of large areas of serpentine in the gold belt. The black sand of Oroville contains, for instance, 1,400 pounds of magnetite, 250 pounds of chromite, and 150 pounds of ilmenite to the ton; this is the average black sand from dredging operations. At Cherokee, Butte County,

[1] Day, D. T., and Richards, R. H., Useful minerals in black sands of the Pacific slope: Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906, pp. 1175-1258.

pannings from old dumps yielded 16 pounds of magnetite and 356 pounds of chromite to the ton. In Calaveras County, black sand from a point near Murphy yielded 1,416 pounds of magnetite and 200 of ilmenite to the ton. Samples from Placerville, in Eldorado County, yielded 32 pounds of magnetite and 1,500 of ilmenite. Sands from North Bloomfield, Nevada County, yielded 8 pounds of magnetite, 200 of chromite, and 200 of ilmenite. From Nevada City, where the bedrock is granodiorite, no magnetite and chromite are recorded, but one sample showed 1,024 pounds of ilmenite to the ton. Gravels from Spanish Ranch, Plumas County, yielded black sand containing 1,760 pounds of magnetite and 218 pounds of ilmenite to the ton. Concentrates from dredges near Marysville contained 1,256 pounds of magnetite and 267 pounds of ilmenite to the ton.

The claim is often made that the black sands contain gold, but as a rule it is safe to assert that this is simply admixed detrital gold.

Platinum is of widespread occurrence in the Sierra Nevada and is always associated with the gold. Its origin is, however, entirely different, for its distribution shows clearly that it is derived from serpentine, peridotite, or gabbro, of which it is a constituent of primary origin, like the magnetite in igneous rocks. The platinum is always accompanied by small quantities of iridosmine and probably also iridium. Bright scales of iridosmine are locally present in considerable quantities. Though of widespread occurrence platinum is not recovered on a commercial scale except at Oroville and Folsom, where it is obtained by panning from the black sand after the gold has been extracted by amalgamation. A few hundred ounces represented the total yield of California in 1908, and of this amount the larger part came from the dredges at Oroville. The examination by Day, referred to above, has, however, shown that the metal is widely distributed in the Tertiary gravels. Its presence was proved in sands from the following places, besides the localities mentioned: In Butte County, Oroville, Butte Creek (Nimshew), Cherokee, Brush Creek, and Buchanan Hill; in Calaveras County, at Douglas Flat; in Nevada County, Rough and Ready and Relief Hill; in Placer County, Butcher Ranch, North Fork of American River, East Auburn, and Blue Canyon; in Plumas County, Genesee, La Porte, Nelson Point, and Rock Island Hill; in Sacramento County, Folsom; in Yuba County, Brownsville and Indian Hill. It is safe to say that platinum is universally present in the gravels of the Sierra Nevada, wherever these have been derived from the erosion of serpentine areas.

Small flakes of metallic copper are observed occasionally.

Detrital pyrite is not uncommon in the gravels. The mineral is derived from rocks of the "Bedrock series," such as amphibolite schist or clay slate; the latter especially is likely to contain well-developed crystals of pyrite. Pyrite may also be derived from the disintegration of quartz veins but is probably preserved from oxidation only where immediately covered by sand or gravel shortly after disintegration. Pyrite in large amount was noted in the White channel of the Hidden Treasure mine, in Placer County; at this place it is in part doubtless derived from the bedrock, of which about 1 foot is extracted with the overlying gravel; but there are also present here waterworn grains of pyrite which indicate the mechanical action of the streams. In the Harmony channel at Nevada City the gravel contains some pyrite derived from quartz veins crossed by the ancient watercourse.

Monazite, a phosphate of the rare metals, which so constantly accompanies the gold in some districts—as in the South Mountains of North Carolina and Idaho—is rather conspicuously absent in the gravels of the Sierra Nevada. Small amounts were identified by Warren from Rough and Ready, Nevada County. Rutile is found occasionally. Cassiterite, or oxide of tin, has been reported by Edman from Plumas County.

Zircon, on the other hand, is universally present and locally in considerable quantities. Black sand from Placerville, according to Day's report, contained 176 pounds of zircon to the ton, and similar material from the North Fork of American River in Placer County contained 340 pounds to the ton. The greatest relative quantity was found in black sand from a channel in granodiorite at Nevada City; it yielded 928 pounds to the ton.

Garnet is another mineral of wide distribution, especially in the vicinity of granitic contacts. It is usually found in small rounded grains of red to purplish color. It is nowhere very abundant,

the largest quantity recorded in the black sand being from Rough and Ready, Nevada County; this material contains 446 pounds to the ton.

Of other materials there is little of interest to record. Olivine, epidote, and pyroxene occur here and there in small grains; the larger part of these minerals have been destroyed by oxidation before the accumulation of the gravels. In sand from the Hidden Treasure mine a number of small pale-reddish grains were found which were identified with some doubt as ruby or corundum. Cinnabar and amalgam have been found at the Odin drift mine, Nevada City. It is unnecessary to state that the gravels also contain a large amount of quartz sand.

One of the most interesting of the minerals occurring with the gold and one which requires some special consideration is the diamond. Its occasional occurrence with the gold was known at an early date and was discussed in some detail by Whitney.[1] The occurrences have been summarized by Turner.[2] The principal localities are at Cherokee Flat, in Butte County, and in the gravels at Placerville, Eldorado County. It is said that at Cherokee 56 specimens have been found; at other localities they have been less abundant. The diamonds found have generally been of small size and yellowish color; the largest size reported is about 1½ karats. Turner points out that at all except one of the localities where diamonds have been found in California areas of serpentine occur in the vicinity and he infers that the diamond, like platinum, once formed an original constituent of the peridotites, which were later altered into serpentine. This view is probably correct. On account of the occurrence of numerous diamonds in Butte County some mining operations have recently been undertaken near Oroville to search for the rock from which the diamonds were derived. It is probable, however, that the occurrence is too scattered to make mining operations like those in South Africa profitable. The following list of diamond localities in the Sierra Nevada is taken from Turner's paper:

Eldorado County: Placerville, south side of Webber Hill, White Rock Canyon, Dirty Flat, Smith's Flat.
Amador County: Jackass Gulch, near Volcano; Rancheria, near Volcano; Loafer Hill, near Oleta.
Nevada County: French Corral.
Butte County: Cherokee Flat, Yankee Hill.
Plumas County: Gopher Hill, upper Spanish Creek.

Turner states that a number of diamonds have in recent years been found at Placerville and that his informant, G. W. Kimble, is of the opinion that many diamonds have been crushed in the gravel mills. Undoubtedly the recovered specimens represent but a small fraction of the gems originally present in the gravels.

AUTHIGENETIC MINERALS.

Since their deposition the gravels have for long ages been exposed to percolating surface waters, and at many places the andesitic flows must have furnished a considerable amount of heat, so that it would be safe to infer that for a while at least after being covered by the flows these percolating waters were moderately warm. At the present time the waters are entirely cold. The basins of the Tertiary rivers form in fact reservoirs that gather the descending surface water, which has percolated through the overlying gravels, sands, clays, and volcanic tuffs and breccias. This abundant stored water finds its way to the rivers from a number of springs which in places very clearly mark the line between bedrock and gravel. This percolating action has continued since the deposition of the gravels in Tertiary time and it might be supposed that a great number of minerals would have been formed by it. As a matter of fact, however, the minerals formed in the gravel—the authigenetic minerals—are remarkably few. Carbonates, like calcite and dolomite, are not plentiful. Silica is the substance which has been most generally deposited and the commonly observed cementing of the deeper gravels is probably to be ascribed to a deposition of this substance, most likely in the form of opal or chalcedony. Newly formed quartz has not been observed cementing the pebbles, though small crystals of this mineral have been noted in silicified wood, which in places occurs in large amounts in the gravels. Similar minute crystals, according to C. F. Hoffmann, cover pebbles here and there in the

[1] Whitney, J. D., The auriferous gravels of the Sierra Nevada: Mem. Mus. Comp. Zool. Harvard Coll., vol. 6, 1879, pp. 362–364.
[2] Turner, H. W., The occurrence and origin of diamonds in California: Am. Geologist, vol. 23, 1899, pp. 182–191.

Red Point drift mine, in Placer County. Partly or wholly carbonized fragments of trunks and roots of trees are frequently converted to opaline masses, usually of gray, white, or black color. Pyrite is of common occurrence and has doubtless been formed through the reducing action of organic matter on sulphates contained in the waters. The pyrite is always most abundant near masses of vegetable remains, though in places it coats the surface of pebbles. Assays of such material frequently show small quantities of gold.[1] It is difficult to prove that this gold was originally present in the solution, for minute quantities of gold occur almost everywhere in the gravels. It is believed, however, that such a solution and precipitation of gold may actually have taken place on a small scale. When the gravels become exposed to the air the pyrite or marcasite oxidizes rapidly to limonite, and in many freshly exposed banks the distinction between the upper red and the lower blue parts is prominent. The blue gravel is simply that in which the pyrite or the ferrous silicates have not yet been decomposed to limonite.

As already stated, the placer gold of California is, as a rule, of a high degree of fineness. If it is assumed that this fineness, in the main Tertiary channels, is 920, this means, of course, that 92 per cent by weight is composed of pure gold. The remaining 8 per cent consists almost entirely of silver. Here and there are small quantities of lead and copper, amounting at most to about 0.25 per cent; there is also in places a little platinum and associated platinum metals, but this, of course, is really only a mechanical admixture.

Most of the gold shows a bright surface and deep yellow color, but locally, especially in the fine or scaly gold, each flattened grain is coated by some foreign substance that renders it difficult or impossible of amalgamation. Under the microscope the surface of such scales appears brown, gray, or black. In many cases at least the coating disappears on treatment with acid or by rubbing, and it is inferred that the substance is limonite, silica, or peroxide of manganese.

METHODS OF MINING.

GENERAL OUTLINE.

The scope of this report does not include a description of the methods of mining, but it will be advisable to sketch in the briefest outlines the processes employed for extracting the gold from the gravels. For further information the reader is referred to the works cited below:

BOWIE, A. J., Jr., Hydraulic mining in California, 1885.
DUNN, R. L., Drift mining in California: Eighth Ann. Rept. State Mineralogist, 1888, pp. 736–770.
HAMMOND, J. H., The auriferous gravels of California: Ninth Ann. Rept. State Mineralogist, 1890, pp. 105–138.

There are practically only two mining methods to be considered in exploiting the Tertiary auriferous gravels—hydraulic mining and drift mining. In the former a stream of water is directed against the gravel bank in the open, and the force of this stream breaks the gravel down and sends the disintegrated mass to the sluices, where the gold is recovered. In drift mining tunnels are driven in bedrock underneath the channels and when the channels are reached the richest stratum, resting immediately on the bedrock, is extracted by underground mining methods and washed at the mouth of the tunnel. Where it is impracticable to reach the deposit by a tunnel, shafts or inclines may be put down, involving a greater expense in pumping water. Other methods, like dredging or the use of the steam shovel, are not ordinarily practicable. The dredging gravels of the Great Valley are much later than the Tertiary deposits of the Sierra and are believed to be of Quaternary age.

HYDRAULIC MINING.

The method of hydraulic mining (illustrated in Pls. III, *A*, p. 20, and IV, *B*, p. 24) was developed in California, and from a small beginning a wonderful perfection was attained, especially in regard to the magnitude of the operations. From 1870 to about 1883 this method of mining was at its culminating stage. The enormous scale on which it was practiced necessitated the dumping of exceedingly large quantities of débris into the narrow gorges of the

[1] J. A. Edman (Min. and Sci. Press, Dec. 15, 1894) reports auriferous pyrite from French Corral, Nevada County, and states that nodular and granular pyrite from a gravel mine in Butte County yielded gold at the rate of $173 to the ton.

torrential streams of the range. These streams rapidly carried the tailings down to the Great Valley. Here the river channels became choked, overflows damaged the value of the land of the Great Valley, and fears were entertained that lower Sacramento River would soon cease to be navigable and that San Francisco Bay would suffer from the deposition of fine silt. Finally laws were enacted which practically prohibited hydraulic mining in the Sierra Nevada, except under the most stringent conditions with regard to the storage of tailings, and thus it has happened that an industry which annually added many millions of dollars to the gold production of California has been forced to suspend operations almost entirely. In 1908 the total production of gold from hydraulic mines in the territory embraced by this report amounted only to about $170,000.

The opening of a hydraulic mine requires a great deal of capital for the construction of the necessary ditches and bedrock tunnels. It is rare that sufficient water can be obtained in the vicinity of the mine. Each large hydraulic mine usually has its own system of extensive ditches carrying the water from the upper rivers or from artificial storage basins in the high Sierra. Such ditches furrow the canyon sides of the more important rivers of the range, and the total amount of money invested in such enterprises doubtless approaches $100,000,000, as estimated by Hammond. With the prohibition of hydraulic mining on a large scale many of these water systems became useless for the purpose intended and have for the last 20 years been used largely for irrigation and power. It is generally impossible to carry on hydraulic mining by following up the old channels; an artificial outlet must be constructed for the débris, and thus long tunnels have been run, piercing the rim of the deposit from a neighboring canyon side. In these tunnels the long sluices are generally contained, and below their portals are a number of so-called undercurrents in which the gravel is comminuted by successive drops and the fine gold caught. The tunnel of the North Bloomfield Co. in Nevada County is 7,874 feet long and cost about $500,000. As long as simply the upper gravels are worked such tunnels are not necessary, but as the principal pay is near the bedrock they become sooner or later a necessity for most hydraulic mines. From the bulkheads the water is carried down to the working place in wrought-iron pipes, mains 22 inches in diameter being used in many of the large mines. The pressure used is often 200 or 300 feet. The stream is discharged from "monitors" or "giants," with nozzles from 4 to 9 inches in diameter. The amount of water used for each monitor is sometimes as much as 500 inches, or about 5,000 gallons a minute. The gravel banks attacked are in places over 200 feet in height, but it is usual to divide such banks into two or more benches. Previous to disintegration by the stream of water the bank is generally blasted to loosen the gravel. Small tunnels are driven into the bank and crosscuts from them parallel to the face of the bank. In these crosscuts large quantities of low-grade dynamite are exploded. The sluices are usually lined with heavy planks and paved with rocks or wooden blocks, between which the gold settles. The sluices are invariably several hundred feet and at some mines several thousand feet in length, and their grade is usually from 3½ to 4½ per cent. Quicksilver is always added to the sluices in order to catch the gold.

Since the prohibition of the dumping of débris into the rivers hydraulic elevators have been used at some places in order to deposit the tailings in neighboring pits. By means of these elevators the gravel washed from the bank is forced up through a pipe by water under heavy pressure.

LEGISLATION CONCERNING MINING DÉBRIS.

The story of the protracted contest between the miners and the owners of the valley lands can not be told in full at this place. An excellent summary has been given by C. G. Yale,[1] from which the following account is in part condensed. As the débris from the mines was allowed to go where it might, it lodged in the narrow canyons, sometimes filling them to a depth of 20 to 50 feet. (See Pls. XII and XIII.) Each winter's freshet swept large masses of this débris down into the valley and caused overflows during the spring. In many localities thousands of acres of orchards and farming lands were almost entirely covered by sand and gravel.

[1] Mining débris legislation, in California mines and minerals, pub. by California Miners' Association, San Francisco, 1889, pp. 255–262.

This condition of affairs brought on numerous suits and much controversy. Finally, in the test suit of Woodruff *v.* The North Bloomfield Mining Co., the miners were beaten, and the United States Circuit Court gave a decision which resulted in closing not only the mine named but all the principal hydraulic mines in the central part of the State located on rivers which drained into the Sacramento and the San Joaquin. The mining company was perpetually enjoined and restrained from discharging and dumping into Yuba River or any of its branches any tailings, sand, clay, or gravel, and also from allowing others to use the water supply of their mines for washing such material into the rivers or streams. As a result of this decision the large mines were closed, and many costly works were allowed to go into decay. Mining camps were deserted, and large districts were depopulated. Many of the small miners, however, persisted in continuing to work their mines, and the Anti-Débris Association, composed of farmers of the Sacramento Valley, carried on an organized opposition to hydraulic mining. Long and costly litigation and bitter controversy between the farmers of the valley and the miners of the mountains continued for years. The companies which sold water to the miners were enjoined from such sales. The feeling between the parties was intense, and at times the agents of the Anti-Débris Association—the spies, as the miners termed them—ventured into some districts at the peril of their lives.

In 1878 the Legislature of California began to take an interest in the matter, and the State engineer was directed to investigate the extent of the débris and its effect upon the rivers and adjacent lands. At an early date the Federal Government also authorized investigations of this complicated question, because of its bearing on river navigation and on the condition of harbors. A provision in the river and harbor act of June 14, 1880, directed such examination and surveys to be made as might be found necessary to devise a system of works to prevent further injury to the navigable waters of California from the débris of hydraulic mines. This investigation was undertaken by Col. J. H. Mendell, of the Corps of Engineers, aided by Lieut. Payson and Marsden Manson, and the report was issued in 1902.[1] A second investigation was authorized by the act of Congress approved October 1, 1888, entitled "An act for the investigation of the mining débris question in the State of California." The Secretary of War was authorized to detail three officers from the Engineer Corps as a commission for the purpose of examining the question and ascertaining whether some plan could be devised by which the conflict might be adjusted without further damage to the navigable river channels. In 1891 the commission transmitted its report,[2] a valuable document containing full information as to the extent of débris and the amount of gravel removed and remaining.

In 1891 the miners held a convention in San Francisco to memorialize Congress as to needed legislation, and representatives from both mining and farming counties were invited. The report of the engineers made it clear that in many of the canyons dams could be erected which would not only restrain the old material lodged in the river bed but also hold a certain amount of additional tailings. The convention of miners asked Congress to accept and adopt the report of the engineer commission and to take steps at once to put into operation the means suggested, in order that mining might be resumed in the manner indicated without the injury complained of in the past. It was recognized by the convention that until Congress took proper action for the erection of suitable restraining works hydraulic mining was absolutely prohibited by the courts.

The court decision did not prohibit hydraulic mining as such; the decree is against the dumping of débris into the streams, and it would therefore include all classes of mines in case action should be considered necessary. There has never been any objection made, however, against quartz mines and drift mines, as the tailings from these are comparatively small in volume. During the last few years some difficulties have arisen between the miners and farmers on account of the operation of dredges on a large scale in the lower reaches of the rivers, but these differences are now said to have been satisfactorily adjusted.

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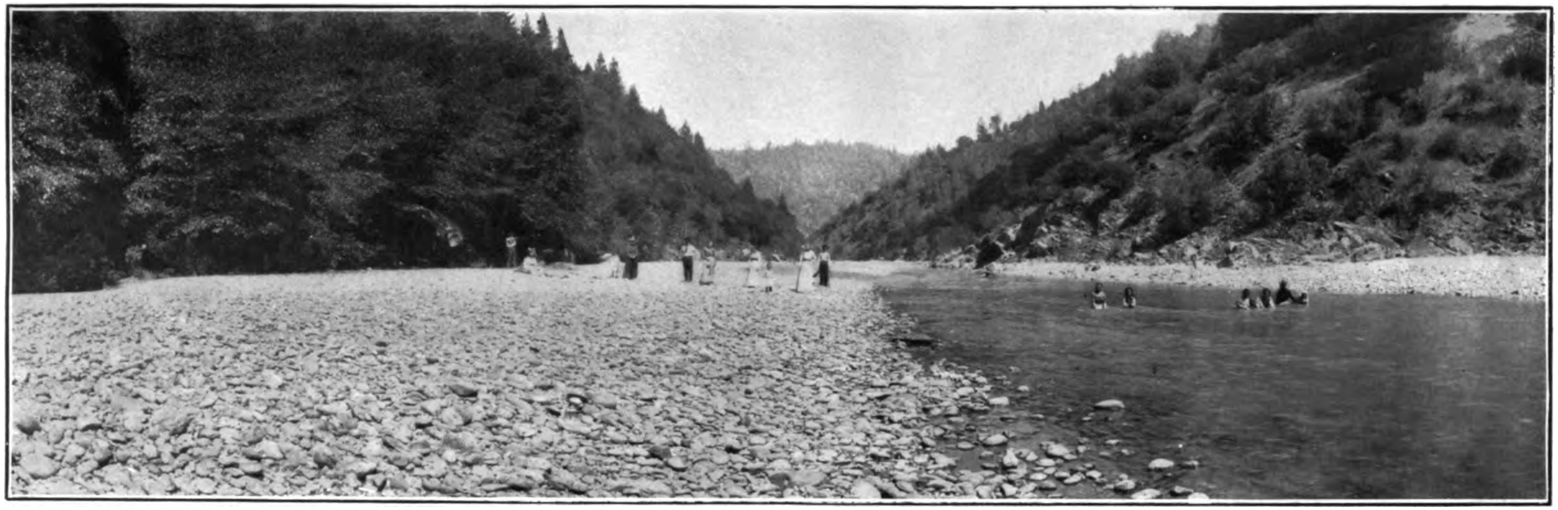
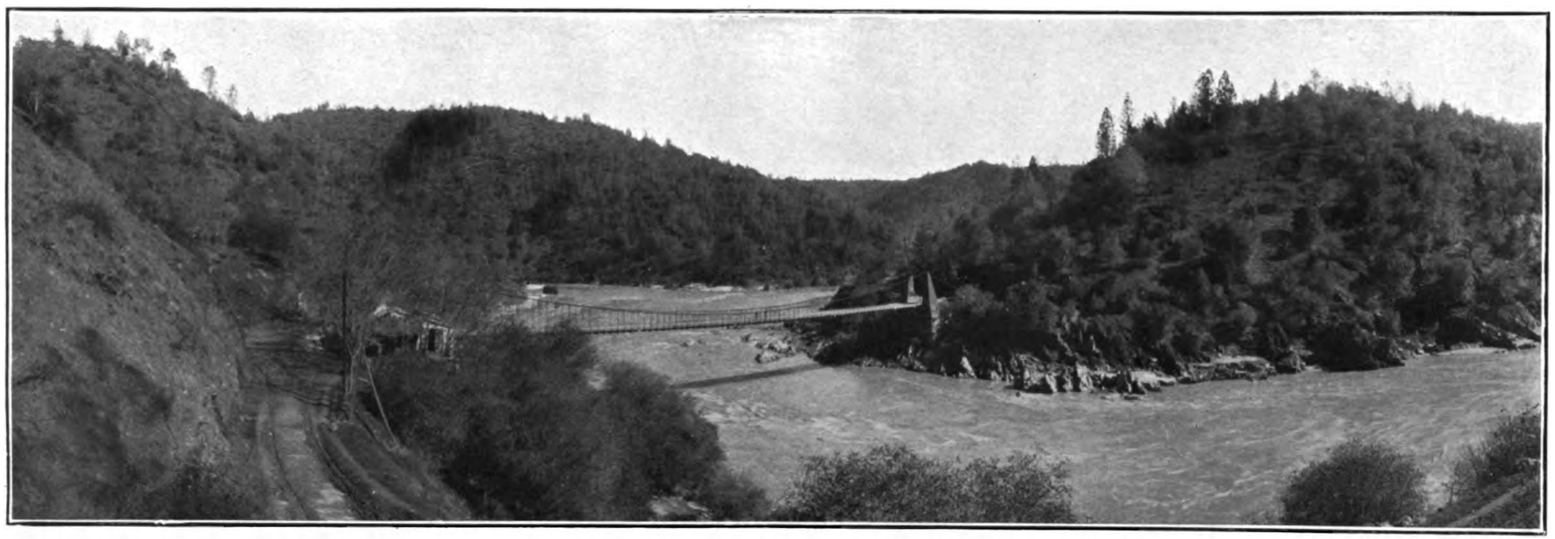
[1] Mendell, J. H., Report upon a project to protect the navigable waters of California from the effects of hydraulic mining: House Ex. Doc. No. 98, 47th Cong., 1st sess., 1882.

[2] Report of board of engineers on the mining débris question in the State of California: House Ex. Doc. No. 267, 51st Cong., 2d sess., 1891.



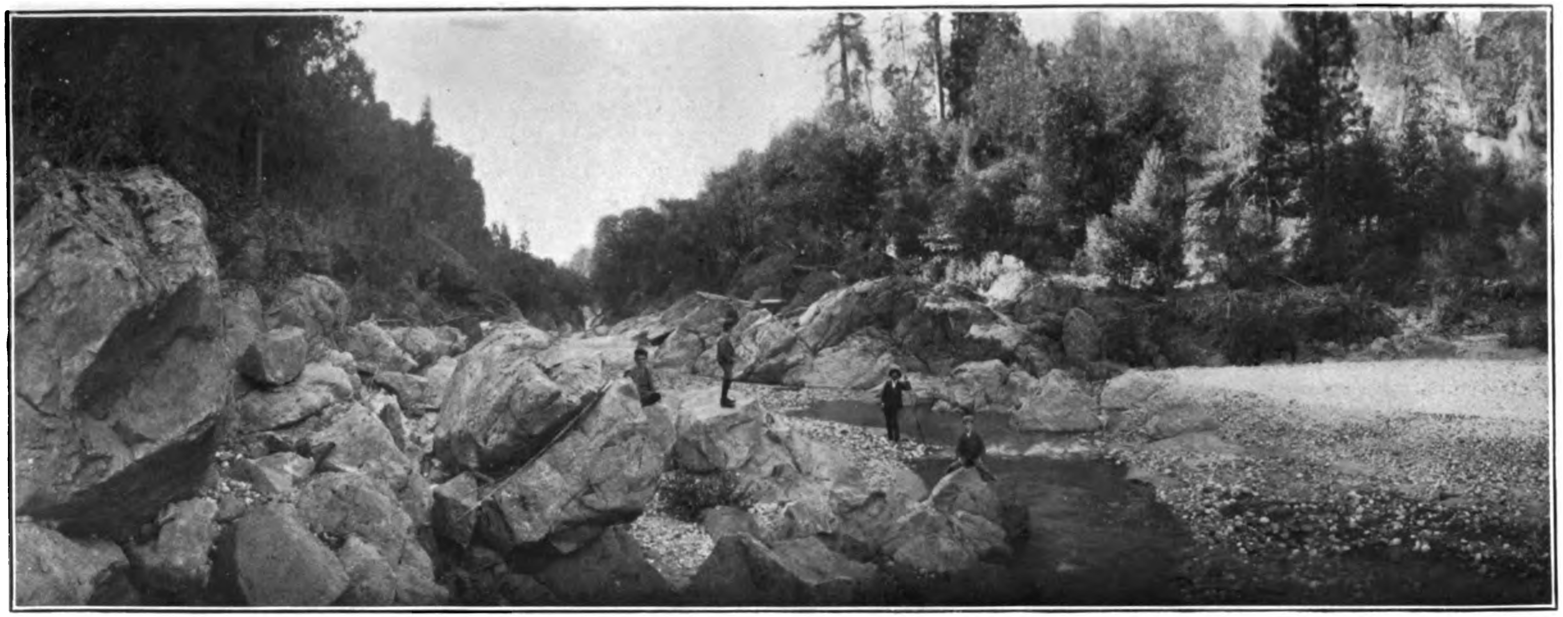
A. AMERICAN RIVER CANYON BELOW AUBURN, PLACER COUNTY, AT LOW WATER.

Photograph by J. C. Hawver. See page 77.

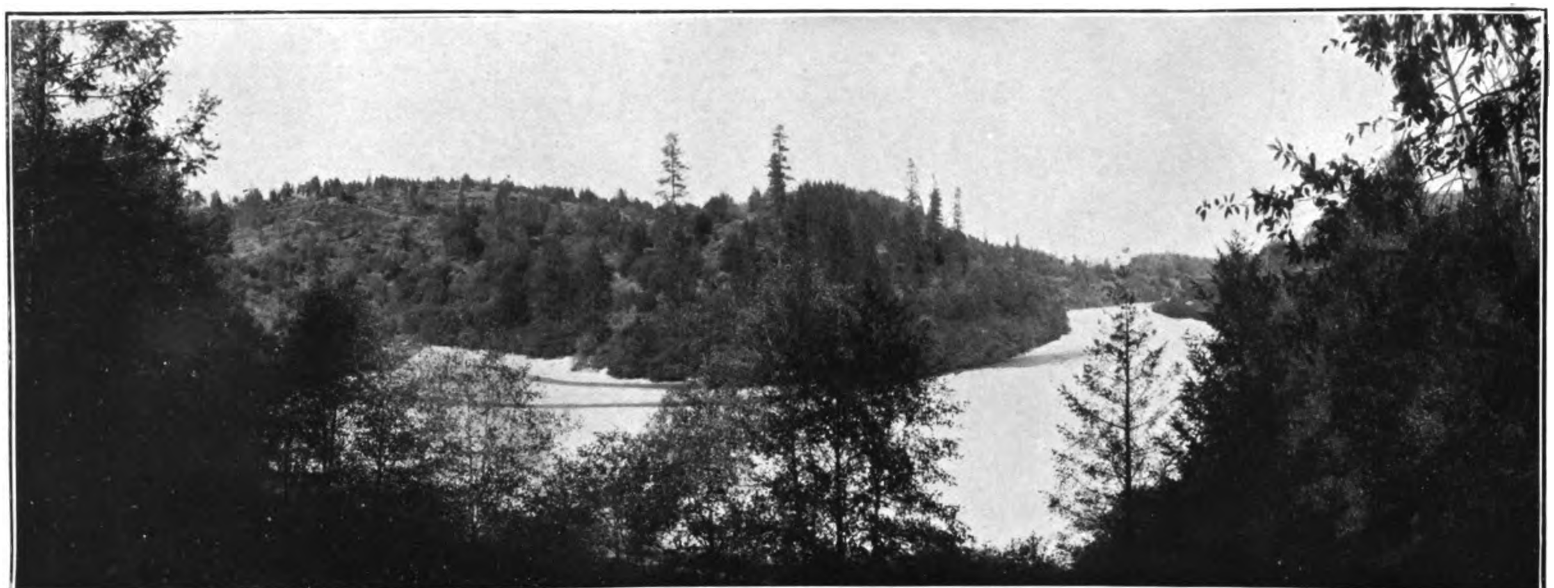


B. FORKS OF AMERICAN RIVER AT BRIDGE ON ROAD FROM AUBURN, PLACER COUNTY, TO GEORGETOWN, AT HIGH WATER.

Photograph by J. C. Hawver. See page 77.



A. BEAR RIVER CANYON, NORTHWEST OF COLFAX, PLACER COUNTY.
Showing deep gorge in granitic rocks below the tailings. Photograph by J. C. Hawver. See page 77.



B. BEAR RIVER ABOVE THE CANYON, NORTH OF COLFAX, PLACER COUNTY.
Showing valley filled with tailings from hydraulic mines. Photograph by J. C. Hawver. See page 77.

In March, 1893, Congress passed the so-called Caminetti act, which permits auriferous gravel mines to be operated by the hydraulic process under certain restrictions and conditions. The essential features of the law are that all mines operated under this system shall impound or restrain their débris or tailings and prevent them from entering the navigable streams or injuring the lands of persons other than the mine owners. Under the act the California Débris Commission, consisting of three officers of the Corps of Engineers, United States Army, was appointed by the President. This commission is empowered to issue licenses for mining by the hydraulic process under this act when it is satisfied that the débris dams or impounding works are sufficient to restrain the débris. The hydraulic miner must make application to the commission for license to mine and submit his plans of the proposed restraining works, which are subject to the approval of the commission. Each application is advertised for a specified time, and the commission holds a hearing at which those who may be opposed to the issuance of a license may state their reasons. When the plans are approved and the necessary works constructed, members of the commission make a personal examination of the work, and if they are satisfied that the débris can be restrained, a license is issued, and the mine may begin operations. If they see any reason to believe, however, that damage may be done to the rivers or to individuals by the operation of the mine, no license is granted, and the mine may not be legally worked. Moreover, even after the license is granted, if the débris, or water carrying too much of it, is for any reason permitted to enter the stream, the license may be recalled. Frequent examinations are made to see that the miners are complying with the law.

Since the passage of this law a number of the hydraulic mines have built the works and received license to mine. The product, however, does not by any means come up to its former dimensions, for the débris must now be run into settling basins behind the dams and allowed to settle, so that a much smaller quantity of gravel can be handled than when the tailings did not have to be cared for. It should be borne in mind that the miners themselves must bear the expense of the restraining works, and for this reason hundreds of the smaller mines have never been started up again, because their owners, having become impoverished by enforced cessation of operations for a series of years, have not the money to construct the necessary impounding works.

The débris commission has supervised hydraulic mining since 1893, and its annual reports, to be found in the annual reports of the Chief of Engineers, contain statements of the number of permits granted. In 1909, for instance, 33 applications for permits to mine were received and 16 were granted. A number of permits are annually revoked owing to the cessation of operations or to failure to maintain the impounding works.

Even after license to mine has been granted by the débris commission some of these mines have been closed by injunction of the State courts. This matter has not yet been brought before the United States Supreme Court for final adjudication and it is, therefore, still a question whether or not a license from the débris commission is final. The commission itself has brought many suits before the United States circuit court enjoining those who have been operating hydraulic mines without a license from it. With these many obstructions to hydraulic mining in the drainage basins of Sacramento and San Joaquin rivers it is not surprising that this branch of the gold-mining industry of California does not materially increase its output. The restrictions do not apply to hydraulic mines in the drainage basin of Klamath River, in Trinity and Siskiyou counties, for this is a nonnavigable stream and empties directly into the Pacific Ocean. There is little reason to hope for relief for the mining industry in the counties of the Sierra Nevada. It is undoubtedly true that the damage was caused mainly by a comparatively small number of large mines, and that many small operators could be allowed to work without material injury to the rivers. In a report on the production of metals in California for 1908, C. G. Yale states that there is much complaint from the hydraulic miners in districts to which the Caminetti law applies concerning the somewhat severe restrictions placed upon them by the California Débris Commission. In many places where formerly brush or log restraining dams were considered sufficient, concrete or stone dams are now required. Naturally little or no capital is being invested in hydraulic mining.

The projects of the engineers also included a provision for holding and storing the enormous quantities of mining débris now resting in Yuba River, by means of works between Smartsville and Marysville, designed to separate the coarse material from the fine, holding and storing both kinds as they are brought down the river, and also to confine the low-water channel in the lower reaches within narrower limits in order to hold in place the extensive deposits already there. These results are sought to be accomplished by means of restraining barriers in the bed of the river and by a settling basin adjoining the river on the south. The first of these barriers was well under way and had been completed to a height of 14 feet when it was destroyed by the flood of March, 1907. Barrier No. 4, at Daguerre Point, is completed and by means of longitudinal cobble dams erected by the dredging company operating in the vicinity the river is now confined to a relatively narrow channel on the north side.

DRIFT MINING.

In drift mining it also becomes necessary to open the deposit by bedrock tunnels piercing the rim; for it is only exceptionally possible to enter the channel at the point where it emerges from underneath the lava cover and follow it upstream. Where the inlet of the channel is accessible a deep bedrock tunnel is likewise needed because otherwise the grade could not be maintained. A few of the channels, as at the Derbec mine in Nevada County and the Thistle shaft in Sierra County, have been opened by vertical shafts, at least as a preliminary step. In such cases the gravels must be rich in order to pay for the heavy additional expense of pumping. The California miner is justly afraid of this expense. It must be remembered, however, that most of the drift mines in Victoria, Australia, are developed by this means and that there continuous pumping is a preliminary step which often lasts for two or three years. The water stored in the channels of California is a limited quantity which can be at least approximately calculated and which in many channels does not compare with the quantity the Australian miners have to handle. More commonly, in channels of moderate depth, inclines are employed; several of the mines on the Harmony channel near Nevada City were opened in this manner. In most places, fortunately, the topographic features favor working through bedrock tunnels. In order to prevent the failure of the enterprise it is necessary to calculate closely the probable depth of the channel in the ground to be worked. A great number of failures may be cited where the tunnel was located too high and one or two mines are known where the tunnel was found to be entirely too low and necessitated expensive raises. By means of extensive geologic and topographic examinations many channels have been successfully located; the work of Ross E. Browne and C. F. Hoffmann on the Forest Hill divide represents excellent instances of such high-class examinations. The bedrock tunnel is preferably retained as a working adit, and raises about 200 feet apart are made from it into the gravel. From these raises drifts and crosscuts are run into the gravel deposit with a view of extracting the gold-bearing material as in a horizontal coal seam. The gravel is rarely worked to a greater height than 5 feet. Special difficulties are experienced where the bedrock is uneven and in such places the handling of the gravel becomes more expensive. From the gravel shoots the material is carried to the mouth of the tunnel in cars holding from 1 to 2 tons; this is usually done by hand or horsepower; in one mine—the Hidden Treasure, in Placer County—an electric locomotive is used.

Outside of the tunnel the further treatment depends on whether the gravel is loose or cemented. If loose it is simply dumped into the floor of a washhouse and the material is washed into the sluices by means of a small hose and nozzle. Gravel of this kind is washed at the Hidden Treasure mine. At this mine, which was visited in 1901, about 400 tons a day were extracted. The sluices were 1,600 feet long and doubled at the upper end to facilitate frequent clean-up.

The first sluice, about 80 feet in length, was paved with car wheels alternating with Hungarian riffles; farther down rock pavement was used. The sluices were 20 inches wide in the bottom and at their lower end one undercurrent was installed. Frequent clean-ups were made in the upper 100 feet, but the lower part of the sluice was cleaned only at considerable intervals.

At the Red Point mine a similar plan was adopted, but between the several shorter sluices drops were arranged in order to facilitate the disintegration of the gravel. In the upper sluice

no quicksilver is used, and the clean-up takes place every day or every third day according to the richness of the gravel. All the other sluices are provided with quicksilver. The grade of the sluices is 14 to 15 inches in 12 feet.

Where the gravel is cemented it is sometimes allowed to slack on the dump before being washed, but as this is rarely practicable when working on a large scale it must usually be crushed. The most common treatment is crushing in stamp batteries with coarse screens, the gold being caught with quicksilver in the battery or on plates. Several other plans have been tried, one of which consists in disintegrating the material in revolving barrels containing iron rails against which the gravel falls and is broken up.

At the Big Dipper drift mine, in Placer County, the gravel is first dumped on a 1½-inch grizzly; everything above this size goes through the rock breaker, except the big bowlders, which are taken out and dumped separately to be washed later in order to recover the fine gold which clings to the surface. The crushed material goes to a 10-stamp mill, the weight of the stamps being 1,150 pounds and the drop about 7 inches. Quicksilver is supplied in the battery, which is fitted with a 9-mesh screen. From the battery the pulp flows over to inclined boxes 20 inches wide and 10 feet long, with three catches containing quicksilver through which the pulp is forced to pass. After passing over a similar but shorter table it is discharged into a rock-paved sluice 150 feet long provided with an undercurrent at the lower end. Nearly all the gold is caught in the battery or in the first box riffle. The duty is about 10 tons to the stamp. Ordinary amalgamating tables were used in the beginning, but were later discarded for the present arrangement.

The cost of drift mining varies considerably, but has not changed greatly during the last 20 years, except at the few places where mining is done on a larger scale. Hammond, in the publication cited above, gives the cost at 90 cents to $1.25 a cubic yard for loose gravel, and $1.75 to $3.50 a cubic yard for cemented gravel. F. Chappellet [1] states that at the Mayflower mine, in Placer County, the mining cost $1.19 a ton and that the milling with steam power amounted to 25 cents a ton, giving an entire cost of $1.44. At the Big Dipper mine the cost, according to G. B. Hobson, is $1.85 a ton. At the Hidden Treasure, where the gravel is not milled and the work is done on a larger scale, the cost per ton is as low as 92 cents.

In contrast to many Australian drift mines, the gravel in the California mines rarely contains much clay, owing to the prevailing harder bedrock and the greater fall of the ancient rivers. Consequently the Australian methods of puddling, or comminuting the clay by revolving drags in pans, are practically unknown in California.

Further references to methods of drift mining may be found in the papers cited below:

CARVER, L. H., An experience in drift mining in hard cement gravel: Min. and Sci. Press, Jan. 3, 1903.
GASSAWAY, A. D., The Magalia drift mine: Min. and Sci. Press, Apr. 8 and 15, 1899.
RADFORD, W. H., Hydraulic mining in very low grade gravel: Pacific Coast Miner, Jan. 24, 1903.
Timbering in drift mines Min. and Sci. Press, July 25, 1896. (Editorial.)

PRODUCTION.

As shown in detail in the following tables, the counties of the Sierra Nevada north of and including Mariposa have produced approximately $57,500,000 in placer gold during the period (1897–1909) for which accurate statistics are available. Of this not more than $15,000,000 came from the gravels of the pre-Tertiary channels. What the total production may have been is impossible to estimate, for the reason that in the earlier years the yield of the placers was not subdivided according to source. The total output of gold in California is estimated at $1,200,000,000 to $1,500,000,000, but about one-fifth of it was derived from quartz veins. The great bulk of this output came from the Quaternary deposits, and about $300,000,000 is a conservative guess for the amount obtained from the Tertiary gravels.

[1] Costs of drift mining: Min. and Sci. Press, Mar. 13, 1897.

Production of gold recovered from 1897 to 1909 by dredging, hydraulic, drifting, and surface placers in counties of Sierra Nevada, Cal., from Mariposa County north.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897	$453,610	$1,061,366	([a])	$1,694,267	$3,209,243
1898	369,547	963,363	([a])	1,196,029	2,528,939
1899	522,549	961,555	[b] $206,302	1,020,592	2,504,696
1900	705,140	978,000	[b] 200,929	689,168	2,372,308
1901	927,609	1,036,947	[b] 471,762	924,600	2,888,156
1902	609,336	895,330	773,522	726,435	3,004,623
1903	418,967	890,351	1,457,831	532,960	3,300,109
1904	467,689	917,504	2,171,711	505,830	4 062,734
1905	336,321	796,554	3,264,050	561,151	4,958,056
1906	396,291	589,402	5,072,359	479,060	6,537,112
1907	354,616	554,764	5,065,437	240,129	6,214,946
1908	187,564	386,910	6,502,996	377,189	7,454,659
1909	108,114	736,462	7,306,634	288,657	8,440,867
	5,858,353	10,768,508	32,493,533	9,236,067	57,476,448

[a] Small amounts included under "Surface." [b] Figures incomplete; actual production somewhat higher.

Production of placer gold in counties of Sierra Nevada, Cal., from Mariposa County north, by counties.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.	Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
Plumas County.						**Yuba County.**					
1897	$21,852	$16,622	....	$170,903	$209,377	1897	$45,150	$1,445	....	$67,164	$113,759
1898	79,797	22,257	....	126,140	228,194	1898	4,453	4,268	....	141,144	149,865
1899	107,742	16,110	....	137,739	261,591	1899	75,030	1,339	....	103,137	179,506
1900	95,884	9,761	....	50,816	156,461	1900	70,834	200	....	29,839	100,873
1901	163,591	24,224	....	31,901	219,716	1901	55,070	871	....	[a] 32,437	88,378
1902	101,090	6,787	....	89,840	197,717	1902	46,010	3,565	....	[a] 97,539	147,114
1903	48,944	29,532	....	58,549	137,025	1903	25,965	2,606	$25,736	71,079	125,386
1904	19,016	10,975	....	67,649	97,640	1904	17,651	400	74,263	43,148	135,462
1905	9,613	12,406	....	69,863	91,882	1905	12,984	1,355	188,967	58,359	261,665
1906	12,280	6,355	....	100,963	119,598	1906	3,416	....	1,205,165	45,637	1,254,218
1907	103,342	5,005	....	20,118	128,465	1907	5,240	918	1,688,032	52,782	1,746,972
1908	26,060	7,637	....	69,316	103,013	1908	543	60	1,969,079	28,863	1,998,545
1909	2,000	9,718	....	40,046	51,764	1909	1,659	....	2,441,919	12,527	2,456,105
					2,002,443						8,757,848
Sierra County.						**Nevada County.**					
1897	$61,964	$89,310	....	$146,141	$297,415	1897	$186,015	$136,499	....	$149,117	$471 631
1898	48,610	58,463	....	98,279	205,352	1898	146 091	76,865	....	62,550	285,506
1899	87,608	48,796	....	60,888	197,292	1899	123,911	40,015	....	68,700	232,626
1900	136,860	64,942	....	44,729	246,531	1900	156,811	77,306	....	67,904	302,021
1901	166,499	77,860	....	36,326	280,685	1901	182,900	109,983	....	43,276	336,159
1902	81,591	66,891	....	56,002	204,484	1902	141,093	18,761	....	65,329	225,183
1903	51,805	80,329	....	42,751	174,885	1903	124,439	122,570	....	39,876	286,885
1904	46,651	139,937	....	34,840	221,428	1904	106,730	173,001	....	30,539	310,270
1905	41,734	77,077	....	10,306	129,117	1905	87,712	220,365	....	42,559	350,636
1906	47,904	46,397	....	24,205	118,506	1906	117,724	135,182	....	11,105	264,011
1907	42,749	48,551	....	3,003	94,303	1907	77,362	45,852	....	8,593	131,807
1908	41,521	30,613	....	37,497	109,631	1908	45,890	28,030	....	14,130	88,050
1909	47,538	21,686	....	34,108	103,332	1909	11,306	368,476	....	14,832	394,614
					2,382,961						3,679,399
Butte County.						**Placer County.**					
1897	$22,205	$122,132	....	[a] $315,865	$460,202	1897	$61,651	$670,039	....	$482,472	$1,214,162
1898	1,550	47,633	....	[a] 197,400	246,583	1898	30,704	740,792	....	380,594	1,152,090
1899	7,590	80,210	....	[a] 251,834	339,634	1899	55,000	631,708	....	242,014	928,722
1900	18,274	35,145	....	[a] 243,123	296,542	1900	157,452	620,813	....	113,645	891,910
1901	91,355	109,067	....	[a] 450,752	651,174	1901	175,011	552,802	....	89,691	816,504
1902	86,024	63,464	$614,380	104,549	868,417	1902	82,382	484,858	....	126,002	693,242
1903	33,176	64,064	1,329,998	48,069	1,475,307	1903	67,185	331,002	....	170,441	568,628
1904	67,701	121,983	1,632,507	87,079	1,909,270	1904	119,500	347,019	....	122,520	589,039
1905	48,039	133,567	2,261,887	136,804	2,580,297	1905	93,481	200,979	....	106,837	401,297
1906	37,220	102,908	2,768,782	101,207	3,010,117	1906	138,615	201,076	....	130,222	469,913
1907	18,375	22,158	2,697,092	48,103	2,785,728	1907	89,428	216,240	....	38,863	344,531
1908	12,736	13,878	3,043,151	56,162	3,125,927	1908	44,155	180,504	....	42,382	267,041
1909	15,265	13,597	2,890,273	43,168	2,962,303	1909	2,242	135,716	....	62,812	200,770
					20,711,501						8,537,849

[a] Surface placer output includes production recovered from dredging operations.

Production of placer gold in counties of Sierra Nevada, Cal., from Mariposa County north, by counties—Continued.

Sacramento County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897	$27,536			$65,514	$93,050
1898	15,000			42,301	57,301
1899	3,000	$90,000		22,906	115,906
1900	17,052	109,926		50,015	176,993
1901	14,000	123,839	(a)	91,739	229,578
1902		225,030	$155,194	46,000	426,224
1903		213,867	102,097	15,000	330,964
1904		41,928	348,990	19,800	410,718
1905		45,000	610,671	36,500	692,171
1906		48,824	921,300	16,500	986,624
1907		127,075	649,511	14,387	790,973
1908	569	52,365	1,109,196	3,925	1,166,055
1909		115,243	1,534,136	20,435	1,669,814
					7,146,371

Eldorado County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897	$6,022	$17,990		$44,345	$68,357
1898	17,188	7,585		48,913	73,686
1899	7,942	2,194		44,791	54,927
1900	6,277	10,480		37,279	54,036
1901	18,700	9,800		53,446	81,946
1902	7,400	4,528		59,856	71,784
1903	12,849	14,106		48,496	75,451
1904	18,226	33,481		39,251	90,958
1905	2,900	55,685		27,788	86,373
1906	300	18,846		25,587	44,733
1907	8,190	20,666		14,689	43,545
1908	2,600	38,148		96,106	136,854
1909		34,520		28,849	63,369
					946,019

Amador County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897	$4,970	$3,000		$111,734	$119,704
1898				15,500	15,500
1899	950	7,994		24,360	33,304
1900	2,300	12,557		26,690	41,547
1901		5,951		38,536	44,487
1902	3,320	2,217		46,650	52,187
1903	1,300	1,060		12,791	15,151
1904	2,112	100		23,900	26,112
1905	2,262	420		47,099	49,781
1906	5,625	6,490		16,800	28,915
1907	3,830	3,387		8,616	15,833
1908	13,490	3,930		2,198	19,618
1909	18,503	8,925		14,222	41,650
					503,789

Merced County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1907				$822	$822
1908			[b] $182,970		182,970
1909			[b] 228,492		228,492
					412,284

Calaveras County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897	$16,245	$4,329		$61,086	$81,660
1898	26,154	5,500		33,400	65,054
1899	53,776	43,189		28,586	125,551
1900	42,646	20,915		2,576	66,137
1901	37,283	7,400		32,839	77,522
1902	29,051	17,929	$3,948	33,468	84,396
1903	48,304	26,927		20,219	95,450
1904	65,102	42,976	115,951	31,419	255,448
1905	35,596	40,988	202,505	19,913	299,002
1906	21,207	22,144	177,112	6,534	226,997
1907	5,000	63,712	[c] 30,802	28,392	127,906
1908		22,413	198,600	20,566	241,579
1909	8,836	24,982	211,814	11,417	257,049
					2,003,751

Stanislaus County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897				$37,392	37,392
1898				19,400	19,400
1899				10,000	10,000
1900	$300	$15,847		5,065	21,212
1901		13,000		2,700	15,700
1907				569	569
1908			(d)		(d)
1909			(d)		(d)
					104,273

Tuolumne County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897				$25,210	$25,210
1898				12,453	12,453
1899				11,037	11,037
1900	$450	$108		11,345	11,903
1901	18,200	1,950		7,114	27,264
1902	31,375	1,300		200	32,875
1903	5,000	4,053		4,189	13,242
1904	5,000	4,400		3,685	13,085
1905	2,000	8,376		3,018	13,394
1906	12,000	1,180		250	13,430
1907	1,100	1,200		283	2,583
1908		9,332		3,063	12,395
1909	765	4,599		500	5,864
					194,735

Mariposa County.

Year.	Hydraulic.	Drifting.	Dredging.	Surface.	Total.
1897				$17,324	$17,324
1898				17,955	17,955
1899				14,600	14,600
1900				6,142	6,142
1901	$5,000	$200		13,843	19,043
1902				1,000	1,000
1903		235		1,500	1,735
1904		1,304		2,000	3,304
1905		336		2,105	2,441
1906				50	50
1907				909	909
1908				2,981	2,981
1909				5,741	5,741
					93,225

[a] Included in surface production.
[b] Includes dredging production of Stanislaus County.
[c] Includes small amount from a dredge in Shasta County.
[d] Included under dredging production of Merced County.

PART II. DETAILED DESCRIPTIONS BY QUADRANGLES.

CHAPTER 5. THE CHICO QUADRANGLE.

The narrow eastern edge of the Chico quadrangle, in Butte County, lies within the gold-bearing region (see Pl. XIV), the remainder of the quadrangle being covered by the Pleistocene of the valley and the andesitic tuffs of northern California, equivalent to the Tuscan tuff of Diller. The geologic mapping of this quadrangle has not been completed, but the following notes are available from the examinations of the eastern border by H. W. Turner[1] and the writer.

GENERAL GEOLOGY.

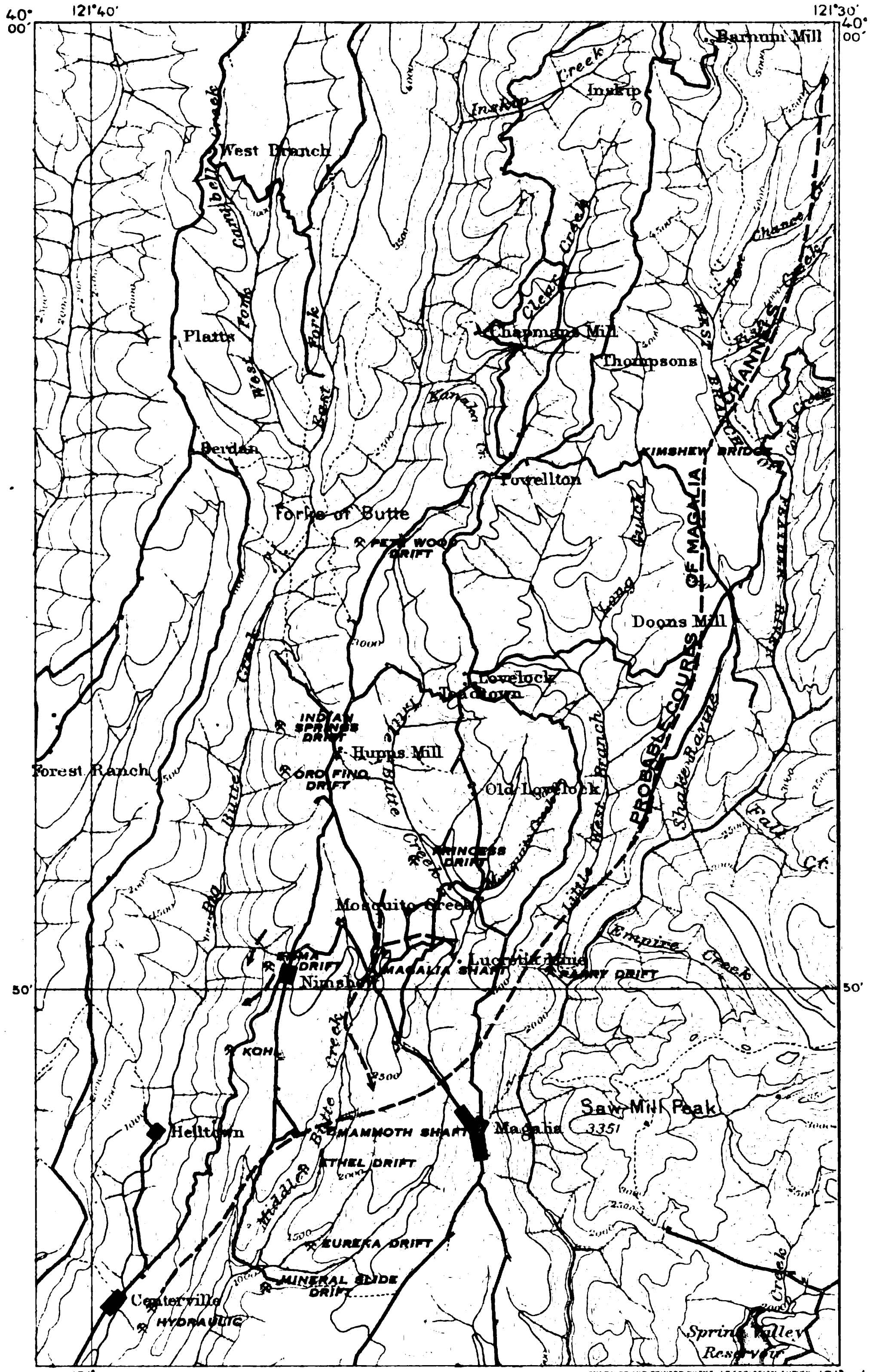
In the adjoining Bidwell Bar quadrangle the principal features are three large areas of granitic rocks representing the last intrusions into an older series of Carboniferous clay slates (Calaveras formation), and large masses of greenstone and greenstone schists, which are altered products of various basic rocks, generally mapped together under the term amphibolites. These greenstones, which in most places form prominent ridges, extend over into the Chico quadrangle, where they dip below the Neocene volcanic tuffs of western Butte and southeastern Tehama counties. A belt of serpentine is exposed in West Branch of Feather River at Magalia and continues thence northwestward toward the Lucretia mine. Clay slates containing fossil plants of Jurassic age are exposed below Monte de Oro, on the north side of Feather River. Farther west a belt of Carboniferous slates and limestones of the Calaveras formation is exposed to the northeast of Pentz's ranch. It is possibly the same belt of clay slates which outcrop in the canyon of Butte Creek above Helltown, serpentines and greenstones appearing farther up. Intrusive diorites occur near Lovelock and Powellton, in the northeastern part of the quadrangle, and in the extreme northeast corner, about Inskip and Chaparral, on the heads of Butte and Chico creeks, there is another area of Carboniferous slates (Calaveras formation) which, according to Diller, extend up into the Lassen Peak quadrangle. A narrow area of the same slates is exposed in Deer Creek, 6 miles east of Butte Meadows.

The amphibolite from Oroville to Oregon City and Cherokee contains a number of quartz veins, of which the Banner mine is the best known, and many small seams rich in gold. At Yankee Hill is the Hearst mine, which is supposed to have yielded $1,500,000 from small shoots and stringers, and many other small pocket mines have been worked in the same vicinity. North of Sawmill Peak, at Magalia, is another belt of quartz veins, the northward continuation of which is believed to have enriched the Perchbaker channel. Many small quartz mines are worked in the vicinity of Inskip, in the northeast corner of the quadrangle. Most of the veins are small and pockety. The annual production from the quartz veins in this part of Butte County is small, rarely reaching $20,000. The whole "Bedrock series" in the Chico quadrangle is impregnated with gold-bearing seams and veins. The gold was concentrated into the numerous Neocene streams which have been preserved underneath the covering lavas along the western margin of the gold belt. Many of the recent streams were also rich and have been extensively mined in the early days. The bars along Feather River were long worked and reworked by the placer miners. The West Branch was likewise rich.

NEOCENE TOPOGRAPHY AND DRAINAGE.

The gentle slope of the foothills, which is so pronounced in the region adjacent to the Central Pacific Railroad, changes decidedly north of Bear River and still more north of Yuba River. The first rocks seen as one approaches the Sierra are massive greenstones—more or

[1] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 548.



TOPOGRAPHIC MAP OF NORTHEASTERN PART OF CHICO QUADRANGLE, CALIFORNIA, SHOWING DRIFT MINES AND NEOCENE CHANNELS

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 Miles

Contour Interval 100 feet

Datum is mean Sea level

less altered diabases, basalts, or augite andesites—which form ridges trending north-northwest and as a rule rise abruptly from the rolling foothills covered with Quaternary gravels. Browns Valley Ridge, north of Yuba River, in the Smartsville quadrangle, is one of the best instances of this tendency. At Oroville and north of it the greenstone ridges also rise sharply from the sediments of the valley, but their direction changes here to more nearly north. North of Cherokee the principal ridge follows the east side of West Branch up toward Magalia, rising to a height of a thousand feet above the gently sloping tuff plateau on the west side of that stream. The same conditions, more or less pronounced, continue northward to Inskip and Chaparral, the latter situated in the Lassen Peak quadrangle. The bedrock ridge here rises to elevations of over 5,000 feet, and the Tuscan tuff spreads westward about 1,000 feet lower. North of this point the lavas of the Lassen Peak quadrangle cover everything, the contact line between the bedrock and the lava fields turns eastward, and the conditions become complicated by the appearance of late Tertiary or Quaternary faulting. This sharp slope was even more pronounced in Neocene time than at present. At Smartsville the Neocene Yuba River broke through the greenstone barrier, which rose a thousand feet above the stream. At Oroville, where the present river has cut through the ridge and exposed the Neocene surface on the north side, the slope of this surface close to the valley is 1,000 feet in a little more than 3 miles. Between Cherokee and Pentz the escarpment is very well marked, and the section from Magalia to Sawmill Peak (Pl. XV; fig. 7, p. 93) shows a rapid rise of 1,500 feet of the Neocene surface. West of Magalia, as shown by the exposures in Butte Creek, the slope is less steep, but the bedrock soon disappears underneath the lavas.

In the area here described there existed no master stream like the Neocene Yuba River, which debouched near Smartsville. Doubtless many smaller streams drained the area, but the Neocene headwaters of the Yuba included the upper reaches of the present Feather River. The range, north of the Yuba, was in Neocene time an elevated region with many ridges trending northwesterly and northerly. The great flows of andesite tuff which followed down Yuba River to the Sacramento Valley failed to cover these rolling uplands and no connected areas of these volcanic flows are to be found below the western foot of the escarpment north of Cherokee. The Neocene gravels of these uplands were easily destroyed by later erosion. The present Table Mountain north of Oroville is the remnant of a flow which evidently originated in the foothills of the range.

There was, as stated above, no Neocene river corresponding to the present Feather. One of the numerous smaller streams taking its place was that whose gravels have been mined so successfully at Cherokee, 10 miles north of Oroville. Neocene shore gravels appear along a north-northwestward-trending line from Cherokee to Mineral Slide and Helltown, on Big Butte Creek. The northeastern part of the Chico quadrangle was drained by a very well defined channel deeply cut through the greenstone ridge. Its upstream course runs from the Mammoth shaft, 2 miles west of Magalia, to the Parry incline, 3 miles north of the same place, and thence up below heavy covering volcanic masses to the northeast corner of the quadrangle. (See Pl. XIV.)

West of this deep channel are a number of small but rich channels draining westward across the present canyon of Big Butte Creek, north of Nimshew.

The Neocene gravel deposits of the Chico quadrangle have been described as shore gravels by H. W. Turner,[1] but except for certain deposits near Helltown and Mineral Slide, on lower Big Butte Creek, such a view seems untenable. Everything indicates, on the contrary, a rough configuration of the Neocene surface and a steep slope from the highlands of the Bidwell Bar quadrangle and the eastern part of the Chico quadrangle to the lower country covered by the Tuscan tuff. Shore gravels may well exist under the covering lavas through the "Lassen Straits" of Diller, supposed to connect the Sacramento Valley with the Neocene lakes of the Great Basin. However, the most northerly exposure of the bedrock formation of Deer Creek, in the southwestern part of the Lassen Peak quadrangle, shows plainly that a deeply eroded stream bed existed here, partly filled with auriferous gravel.[2]

[1] Op. cit., pp. 545, 546.
[2] Diller, J. S., Geology of the Lassen Peak district: Eighth Ann. Rept. U. S. Geological Survey, pt. 1, 1889, p. 416.

VALUE OF THE GRAVELS.

The bottom gravels of the Neocene channels are usually rich, values of $3 to $6 a cubic yard being common. Most of the operations are, however, conducted on a small scale, for the channels are mostly narrow and the bedrock uneven. The drift and hydraulic mines of the Chico quadrangle vary considerably in production from year to year. There are ordinarily from 15 to 25 operators, and the total yearly output ranges from $100,000 to $200,000, the latter figure being nearly reached in 1901. The largest individual production during that year was $52,000. In 1908 the production of the same class of mines was reduced to about $26,500, only about $14,000 being reported from drift mines. Besides there is an output of gold from "surface mines," mainly Quaternary, which in 1908 yielded $56,000. In 1909 about the same production was recorded.

TABLE MOUNTAIN AND OROVILLE.

Table Mountain, north of Oroville, is of especial interest owing to the presence of gravels of many different ages. The geologic history is briefly as follows, beginning with the oldest deposits: (1) Deposition of Chico formation (Upper Cretaceous); (2) epoch of erosion; (3) accumulation of lowest gold-bearing gravels (Eocene?); (4) deposition of Ione formation, underlying Table Mountain; (5) eruption of basalt of Table Mountain; (6) formation of high volcanic gravels of Table Mountain; (7) epoch of erosion; (8) deposition of tuff and lower gravels (late Pliocene) of Oroville; (9) epoch of erosion; (10) deposition of bench gravels of Oroville (Quaternary); (11) epoch of erosion; (12) deposition of present stream gravels. (See Pl. XV.)

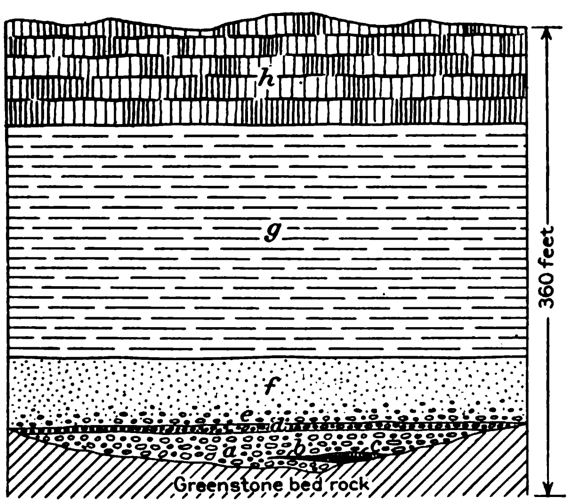


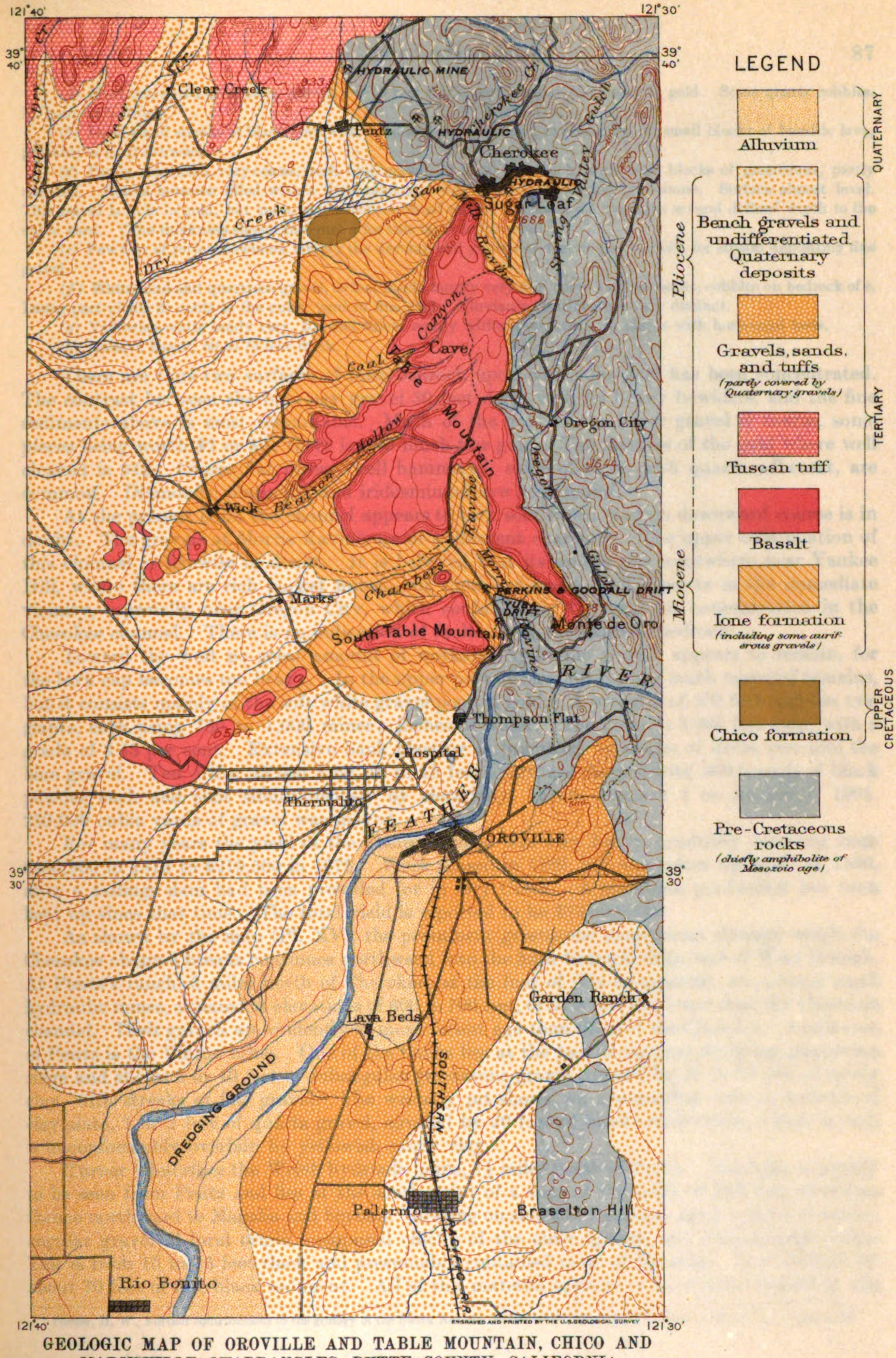
FIGURE 4.—Diagrammatic section of Tertiary gravels, Ione formation, and basalt at the Cherokee mine, Oroville Table Mountain, Butte County. See text for explanation.

There is only one small exposure of the Chico formation in Dry Creek, a mile south of Pentz's ranch, at the northern base of Table Mountain, at an elevation of 300 feet, and the Cretaceous sandstones are here covered by beds containing shells of *Corbicula*,[1] a fresh or brackish water mollusk. The fossiliferous beds are in turn covered by the thick white clays and shales of the Ione formation. A few miles north of Pentz, in Big Butte Creek, the Chico attains an elevation of 1,000 feet, but south of Table Mountain the Ione formation rests directly on the bedrock.

The well-known Cherokee hydraulic mine (Pl. IV, p. 24) is situated at the north end of Table Mountain and has been described briefly by J. S. Diller [2] and in several of the reports of the State mineralogist.[3] The bedrock of the channel mined is exposed for about 4,400 feet, and in this distance the descent is 250 feet in a west-southwest direction. The form is that of a flat trough, the bedrock rising on the south side 150 feet and on the north side 200 feet and being laid bare throughout. Many millions of cubic yards of gravel have been removed. The bottom of the channel is on the whole flat and 700 feet wide. The bedrock is very irregular in detail and covered by large greenstone bowlders. The elevation at the upper or east end is about 1,250 feet; at the lower end, at the hydraulic bank, about 1,000 feet. This channel is not the bed of a main river but rather that of a broad and steep gulch.

The succession of beds is shown in the accompanying diagram (fig. 4). The following is the section, beginning from the bedrock:

[1] Turner, H. W., The rocks of the Sierra Nevada: Fourteenth Ann. Rept., U. S. Geol. Survey, pt. 2, 1894, p. 463.
[2] Tertiary revolution in the topography of the Pacific coast: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 418.
[3] Notably by E. B. Preston, in Eleventh Rept., 1893, p. 155.



GEOLOGIC MAP OF OROVILLE AND TABLE MOUNTAIN, CHICO AND MARYSVILLE QUADRANGLES, BUTTE COUNTY, CALIFORNIA

Scale $\frac{1}{125000}$

1 0 1 2 3 4 Miles

Contour interval 100 feet.
Datum is mean sea level.

1911

(a) Hard cemented greenstone gravel, 5 to 10 feet thick, part angular, very poor in gold. Some quartz cobbles. No gold on bedrock.

(b) Local small streaks of black clay with wood and bark, covered in places by (c) small blocks of basaltic lava, probably a local intrusion.

(d) Partly cemented, very coarse, fresh blue gravel, 20 to 30 feet thick, with large blocks of greenstone, partly rounded. Spaces between filled with a little sand and well-washed quartz and greenstone. Surface almost level. This gravel is rich in gold, but most of it is concentrated on the surface of a. Contains several dollars' worth to the cubic yard. (The thickness shown in figure 4 for this layer is too small.)

(e) Few feet of rotten bowlders, simply the decomposed gravels of d, acting as bedrock for stream depositing fine gravel.

(f) White sand and quartzose gravel, 50 feet thick, mostly very fine, some a little coarser, cobbles on bedrock of e. Lower part yields 25 cents to the cubic yard in fine gold. Fluviatile stratification very distinct.

(g) Yellowish white sandy clay, 200 feet thick, nearly without structure; in places with horizontal beds.

(h) Massive basalt, 50 to 75 feet thick.

There are thus two surfaces of false bedrock upon which the gold has been concentrated. The contrast between the blue pay gravel 30 feet deep, with its heavy bowlders, and the fine sediments above is most remarkable. Much of the gold in the lower gravel is coarse, some pieces being worth $2 or $3; there is also much fine gold. The fineness of the gold where well cleaned is 945. Coarse flat pieces, well hammered, some of them with quartz adherent, are common. Diamonds, platinum, and iridosmium have been found.

At the present bank the channel appears to turn southward, and its downward course is in doubt. The gravels at Morris Ravine are of a different character. The upper continuation of this channel is likewise in doubt. It is believed that its source was somewhere near Yankee Hill, where there are rich pocket mines, but there are many such deposits in the immediate vicinity, especially near Oregon City, which could supply the gold for concentration in the Cherokee channel. There is no indication of faults along the exposed bedrock.

Toward the west no great amount of workable hydraulic ground appears to remain, for the lava cap becomes too heavy. In the upper part of Sawmill Ravine much material remains, but it consists mainly of the soft white gravel poor in gold. A pressure of 350 feet supplies two giants, each using 750 to 1,000 miner's inches of water. The flume is 3,000 feet long, with a grade of 3.45 per cent. Extensive bank blasting is practiced by means of drifts run into the blue gravel. Ten drifts, 35 feet long, 10 to 15 feet apart, are charged with 300 pounds of black powder each and shot simultaneously by electricity. From January 1 to August 1, 1901, 250,000 cubic yards of gravel was moved.

For many years the yield of the Cherokee mine was very heavy, gradually declining from $406,900 in 1875 to $219,500 in 1878. Work ceased in 1889, but was taken up again in 1900, after a tailings dam had been provided for in Dry Creek. A moderate production has been kept up since that time. The total yield is reported to be $13,000,000.

As shown by the map (Pl. XV), the prominent greenstone escarpment through which the Cherokee channel breaks continues northward into the high bedrock ridge east of West Branch. At Pentz's ranch, 3 miles north of Cherokee, at the foot of this escarpment, are several small hydraulic mines, situated at elevations of 600 to 700 feet, or over 300 feet lower than the Cherokee channel. Their gravels are evidently of more recent age than those of the Cherokee. A mile east of Pentz is the Vinton mine. One of the banks lies at the foot of the sharply rising greenstone ridge and shows 8 or 10 feet of subangular greenstone gravel covered by 20 to 30 feet of sandy clay, with streaks of fine gravel. The westerly pit shows, on a somewhat uneven bedrock of clay slate, 1 or 2 feet of quartz gravel, covered by 20 feet of black, coaly shale, which in turn is unconformably overlain by yellowish sandy clay.

Turner[1] describes the Welch hydraulic mine, 1½ miles north of Pentz. The mine is plainly to be seen from Pentz and lies at the south point of a spur of the table of tuff that continues thence northward to Magalia and beyond. Resting on slates of Paleozoic age is a layer of coarse, angular gravel of local origin, composed chiefly of the older igneous and metamorphic rocks. This is from 10 to 15 feet thick and presumably contained most of the gold. It is overlain by about 70 feet of fine black sediment. All of this material appears to have been washed by the

[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 541.

hydraulic method. The next layer is made up of rusty sediments about 10 feet thick; it contains waterworn pebbles of quartz and siliceous metamorphic rocks and is especially remarkable as containing abundant fragments of the black fine-grained basalt of Oroville Table Mountain, which is only 2 miles distant. These fragments, many of which are from 3 to 6 inches in major diameter, are not noticeably waterworn. This layer appears to give evidence that Table Mountain was undergoing erosion at the time the layer was being formed. Overlying it is about 50 feet of soft, light-colored, very fine grained sediments or tuff. A microscopic examination shows the brown friable material to be a true tuff of andesitic origin, made up of microlitic fragments and of broken crystals of plagioclase (in part labradorite), augite, hypersthene, and brown hornblende, all of which are abundantly represented. Overlying this fine sediment is a harder 4-foot layer of basaltic tuff. From this layer to the top of the table, a vertical distance of about 150 feet, all is tuff, with more or less gravel and angular fragments of lava, much of which is basaltic. One layer about 10 feet thick in this mass of tuff is composed of well-rounded lava pebbles, and the top is a heavy bed of dark breccia. The succession made out above may be tabulated as fullows:

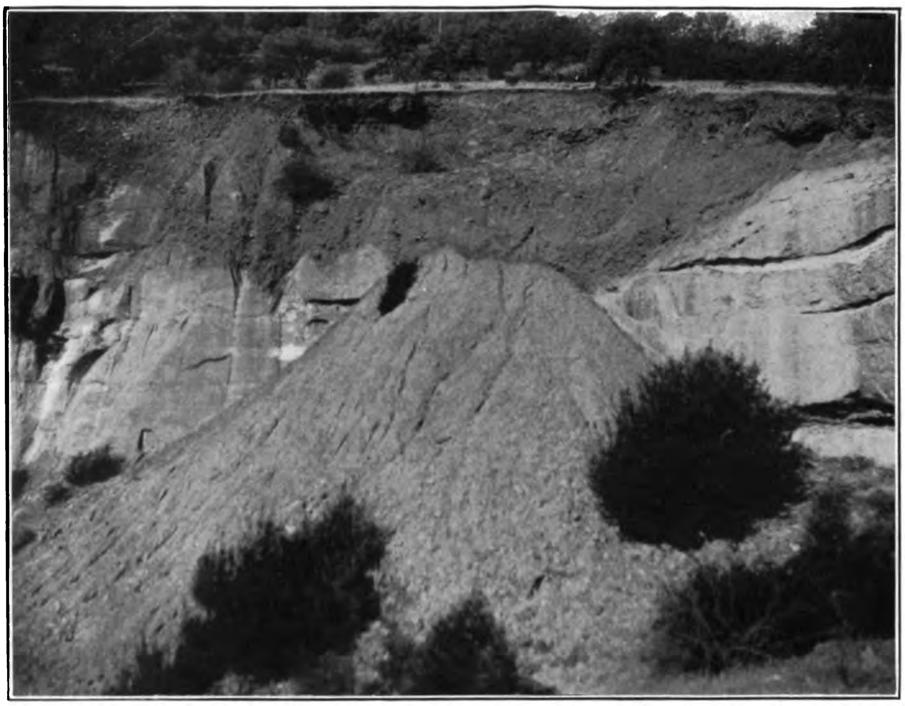
Section at Welch's hydraulic gravel mine, 1½ miles north of Pentz.

	Feet.
Tuff, conglomerate, and breccia; largely basaltic	150
Very fine tuff of andesitic detritus	50
Sand, quartz pebbles, fragments of the older basalt	10
Sand and gravel	70
Angular gravel	10
Base. Paleozoic slates dipping at a high angle.	
	290

It is evident that in this region the Ione formation overlapped a very uneven surface, but no indications of faults have been observed. The andesite tuff is clearly younger than the basalt of Table Mountain, and a certain amount of the Ione formation and basalt was eroded before the volcanic mud stream came down. This epoch of erosion has left deposits of stream gravels, heavy bodies of well-washed basalt cobbles (Pl. XVI, *A*). The gravels of such intermediate channels have been mined near Cherokee, at Sugar Loaf, where they were rich in coarse gold. On the western slope of Table Mountain, at Autzmann's ranch, at an elevation of 500 feet, two tunnels, each 200 feet long, have been driven in such gravels, which rest on clays of the Ione formation and contain fragments of bones.

Along the east front of Table Mountain the basalt generally rests on bedrock at an elevation of about 1,000 feet. A sharp Neocene slope of 500 feet in a mile carries the bedrock down from Monte de Oro to Morris and Chambers ravines, where several hydraulic and drift mines are located on bodies of gravel once overlain by the basalt of Table Mountain.

The elevation of the bedrock at the diggings above the road house on the point of South Table Mountain is 750 feet. On this point an area of about 900 by 150 feet along the rim has been washed. The rim rises 50 feet on each side, forming a distinct shallow trough. The bedrock is greenstone. The bank is 100 feet high, showing 50 feet of white sand with extremely well-washed pebbles, mainly of quartz. The sand shows fine fluviatile stratification. This is covered by 50 feet of yellowish clay in horizontal beds and this in turn by basalt. From this point the bedrock remains near an elevation of 620 feet nearly to the Yuba mine, where it sharply drops to 580 feet. Here there is a considerable hydraulic pit, showing a bank of fine quartz sand with pebbles, underlain by yellowish material containing many pebbles of diabase. This streak is said to contain good drifting pay. Just below this pit, at an elevation of 565 feet, the Yuba tunnel extends a few hundred feet in a westerly direction. A slight incline carries it down to bedrock 20 feet below the portal; at this point the bedrock still pitches into the hill. The breasts of pay gravel show 5 to 6 feet of fine clayey, partly cemented material with many imperfectly washed pebbles of quartz and diabase and much fossil wood. Some pieces up to $2 in value have been found, but most of the gold is much finer. Above is a stratum



A. CHANNEL WITH BASALTIC GRAVEL CUT IN CLAY AND SAND OF THE IONE FORMATION, MORRIS RAVINE, OROVILLE TABLE MOUNTAIN.

Photograph by Waldemar Lindgren. See page 88.

B. HYDRAULIC MINE ON EAST SIDE OF BUTTE CREEK NEAR CENTERVILLE, BUTTE COUNTY.

Showing 100 feet of Tertiary gravels resting on sandstones of the Chico formation and overlain by several hundred feet of andesitic tuff. Photograph by Waldemar Lindgren. See page 91.

of clayey sediments. This gravel, of which a considerable amount has been worked, is said to contain $4 to the cubic yard.

A short distance north of the Yuba mine, on the road toward the Goodall & Perkins mine, the Old Glory shaft is sunk 160 feet deep to the greenstone bedrock, which lies at an elevation of about 510 feet and slopes gently west. Coarse, partly angular greenstone gravel was found, apparently containing little gold. The shaft is dry.

A large hydraulic cut has been made at the Goodall & Perkins mine in the clays and fine gravels of the Ione formation, showing a lowest bedrock elevation of about 560 feet. An incline sunk on the rim between the Old Glory shaft and the Goodall & Perkins mine is said to have found bedrock 100 feet lower than in the Old Glory.

The hydraulic diggings in Morris Ravine were unsuccessfully worked on account of a slide on a clay seam which brought the whole lava bluff above down as fast as it could be hydraulicked off below. Then drifting operations were begun, closing in 1897. The main two tunnels were run at an elevation of about 600 feet, both in a northerly and northeasterly direction, the westerly tunnel being at a somewhat higher elevation and crossing the easterly tunnel. The lower tunnel is 1,700 feet long. Pay was found in the hill in shape of a channel, sloping steeply westward, of pretty coarse blue (greenstone) gravel lying in quartz gravel as if a gully had been cut in the previously deposited fine quartz gravel. The eastern part of the block, 600 feet long and 100 feet wide, was 120 feet higher than the western part. Coarse gold was found, some pieces having a value up to $133. About 12,000 cubic yards was mined, containing according to reports from $4 to $9 a yard. The pitching bedrock, accompanied by an influx of water, presumably stopped the operations.

No bedrock has been found east of these exposures. Heavy masses of clay, with fossil wood, prevail in the south branch of Chambers Ravine.

There seems to be no large, well-defined channel in Morris Ravine, but an even, rather sharp westward slope, which contained several gullies in which coarser and finer gravel accumulated. They certainly do not represent the continuation of the Cherokee channel.

Some leaf impressions have been found in the Ione formation at the Cherokee mine, but their examination did not lead to definite conclusions. Leaves of *Juglans californica* Lesquereux were identified by Knowlton from clays in Morris Ravine.[1]

OROVILLE DREDGING GROUND.

The Oroville dredging ground (see Pl. XV, p. 86) is considered to comprise about 7,000 acres of the present flood plain of Feather River, or a few feet above it, beginning a few hundred yards below town and continuing down for about 5 miles, where the ground gradually gets poorer, and thus more difficult for the dredgers to handle. The width varies from less than a mile to about 2 miles. The average depth of gravel is 25 or 30 feet, increasing to 40 feet lower down on the river. The gravel rests on a false bedrock consisting of a compact volcanic tuff containing no large lava pebbles or fragments. The sidehills as a rule rise rather abruptly 50 to 70 feet above the flood plain, and consist of probably the same tuff covered with heavy Quaternary gravels on top, spreading in sloping plateaus. On slopes this gravel has in places been concentrated and shows evidence of old shallow diggings. Near Oroville and also lower down old Chinese workings are plentiful in the dredging ground, in part worked in open pits by Chinese pump, in part by drifting. Much of the richest ground is thus already exploited.

The deposits consist of heavy gravels, many cobbles being over 6 inches in diameter; even at a distance of 5 miles below Oroville, 6 to 8 inch cobbles are plentiful. At that place one diabase bowlder 2 or 3 feet in diameter was noted. Gravel and sand alternate; sand, coarse gravel, or fine gravel may rest on the bedrock. Most of the gold is in coarse gravel; here and there some is contained in sand. The gold is fine, and some of it may be called flour gold. The tenor ranges from 12 to 20 cents to the cubic yard.

[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 546.

The dredging industry at Oroville has developed rapidly in recent years. In 1901 only 11 dredging machines were at work. In 1905 the product of 15 companies, with about 35 dredges, was $2,262,000. In 1909 13 companies with 26 dredges reported a product $2,743,000.

The bedrock at the Oroville dredging ground is a tuff that is pretty compact, though soft enough to be cut by dredge buckets. It contains small white pumicelike fragments, consisting of volcanic glass; in places, however, the fragments are very small and the tuff looks more like a compact clay. This tuff is exposed all along by dredging 20 to 40 feet below the surface; it also shows in the steep south bank above the tailings level 3 miles below Oroville, where it is capped by gravel, and on the road to Bidwell Bar 2 to 3 miles east of Oroville. On the Wyandotte road it outcrops in the low foothills below the gravel up to elevations of about 400 feet. It appears also one-fourth mile below Oroville bridge, on the north side of the river, below a 30 to 40 foot bench of Quaternary gravel. The contact of this Quaternary river gravel and the greenstone bedrock slopes gently westward, and the contact between greenstone and tuff seems to dip more steeply to the west.

This series of tuffs, sands, and clays, as shown on Plate XV, extends south of Feather River for several miles; probably it underlies the Quaternary gravels of the whole foothill region between the Feather and the Yuba, and it is reported to underlie the gravels at the Yuba River dredging ground. Its thickness is unknown but probably increases rapidly westward. Below Oroville bore holes 80 feet deep have been sunk in it without finding any different material. Its correlation is somewhat difficult. It might be considered the exact equivalent of the Ione formation, but the fact that no tuffs have been found in the Ione formation at Table Mountain is against that correlation. The origin of its volcanic constituent is probably not the slope of the Sierra Nevada. It is more likely that ash showers from the neighboring volcano of the Marysville Buttes contributed to its formation and that it was deposited on the bedrock at the close of the Neocene, before the canyon of Feather River had been cut but after an active epoch of erosion of the older Ione formation. The bedrock relations at Oroville indicate pretty clearly that this series was deposited on the even Miocene slope corresponding to that of the Ione formation on the north side of the river, before the modern canyon had been excavated.

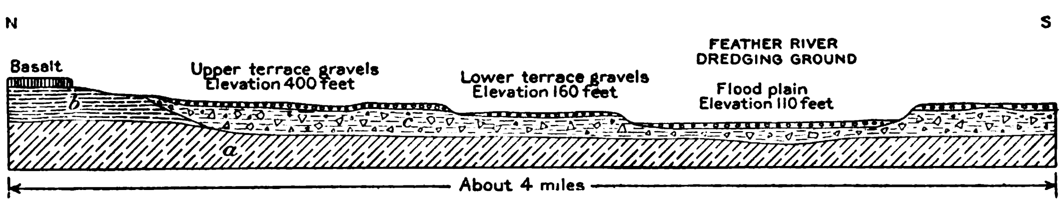


FIGURE 5.—Diagrammatic section across Feather River below Oroville. *a*, Bedrock; *b*, Ione formation; *c*, tuffs of Oroville.

The Quaternary river gravels rest at Oroville on these beds in several fairly well defined benches. (See fig. 5.) At Oroville there is a comparatively narrow, lowest bench 20 feet thick. The bedrock is 30 feet above the river, at an elevation of 160 feet above the sea. Above this there are two rolling benches which have an elevation of 340 to 430 feet, the latter being the maximum elevation of the Quaternary gravels on the Bangor road.

MAGALIA AND BIG BUTTE CREEK.

GENERAL DESCRIPTION OF THE GRAVELS.

Northward from Cherokee the normal andesite tuffs of the Sierra Nevada rest on the slates and greenstones near the West Branch at the foot of the first bedrock ridge of the Sierra. Neocene gravels reappear in Big Butte Creek about 12 miles from the north end of Table Mountain. The canyons of Big Butte and Little Butte creeks are here incised from 1,000 to 1,500 feet below the sloping tuff plateau. At Mineral Slide and Helltown rather heavy gravels rest in broad depressions partly on slate, partly on the eroded surface of Chico sandstones (Upper Cretaceous). They have generally been described as shore gravels by Turner and

others, but it is rather doubtful whether this term should be taken literally. More probably they are river gravels from the broadened channels near the old shore line.

At the Mineral Slide [1] or Magalia Consolidated mine the tuffs are about 600 feet thick, and the contact between them and the bedrock (slate or Chico formation) lies at an elevation of about 1,500 feet on the north, sinking to 1,000 feet on the west side. Several tunnels have been run in and good pay was found on the rim, but the main depression opened by the big tunnel 1,300 feet long contains low-grade gravels of large extent and up to 10 feet thick, gold being scattered throughout the thickness. To the northeast of Mineral Slide, east of the Ethel tunnel, are several smaller channels which run southward toward Mineral Slide.

In the Eureka tunnel,[2] which is about a mile northeast of Mineral Slide, at an elevation of about 1,300 feet, a pay channel on slate bedrock was worked for about 2,600 feet a little east of north. The gravel is said to be subangular, the width of the channel 15 to 40 feet, and the thickness of gravel below the lava roof 2 to 3 feet. The gold is coarse. From 1884 to 1888 $30,000 had been produced. Of late years no work is reported.

Great masses of gravel occur near Centerville on Big Butte Creek. These bodies, of which those of Mineral Slide form an easterly extension, were accumulated at the lower end of the Magalia channel, which came down from the northeast corner of the Chico quadrangle by way of the Parry incline. Excellent exposures of these great bodies of gravel are shown on the east side of Big Butte Creek, on the road from Nimshew to Centerville. The slate bedrock slopes gradually southward from Nimshew to a point opposite Helltown, where it has an elevation of 1,500 feet. It then rapidly drops to 1,000 feet, and along the slopes great masses of well-washed gravel are seen, mostly of granite and metamorphic rocks and in places over 100 feet thick; they are covered by andesitic tuffs (Pl. XVI, *B*, p. 88). Near the same place the Upper Cretaceous sandstone (Chico formation) appears in horizontal strata, intercalated between the gravels and the bedrock of Paleozoic slates. The contact of the slates and the Chico formation dips rather steeply toward the south and the last outcrops of the slates are seen about 2 miles above Centerville in Big Butte Creek. This gravel-filled depression doubtless continues valleyward toward the city of Chico, but its exact course has not been traced. The Neocene gravels rest on fairly level Chico beds and at Centerville lie at an elevation of 950 feet, about 400 feet above the creek bottom on both sides of Big Butte Creek. There are several small hydraulic cuts near Centerville, but no work is carried on at present. The gravel is reported to be of low grade, though good pay was found in places along the rim. In some of these so-called shore gravels basalt pebbles were found, but they probably are confined to an upper stratum directly underlying the andesitic tuff, which is here 600 to 700 feet thick. Turner [3] makes the interesting statement that the lower part of the Chico formation contains gravels which carry gold, though they are of too low grade to be worked.

On the road from Magalia to Oroville, by way of Paradise and Clear Creek, no Chico sandstones, Neocene auriferous gravels, nor Ione clays are seen. The tuff continues almost to the level of the valley, alternating in places with clay beds and volcanic gravels. All these relations strengthen the conclusion that the Ione formation had suffered much erosion between the eruption of the Table Mountain basalt and that of the andesitic tuffs. The lava of Table Mountain probably issued from one or more local vents, while the enormous masses of tuff covering a large part of the Chico quadrangle found their way down the slope as mud streams from the volcanoes in Lassen County. As suggested by Turner, the andesitic tuffs of this quadrangle (equivalent to the Tuscan tuff of Diller) may be of somewhat later age than those found on the slope of the Sierra farther south.

If the figures given above are correct, there is a fall of about 330 feet in 4 miles between the Parry incline and the Ethel tunnel, making a grade of 82 feet to the mile. The grade between the gravels at Centerville and the Ethel tunnel would be about 100 feet to the mile.

[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 545; Twelfth Ann. Rept. California State Mineralogist, p. 85.

[2] Tenth Rept. California State Mineralogist, p. 117.

[3] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, p. 547.

THE MAGALIA CHANNEL.

The first definite location of the Magalia channel northeast of the "shore gravels" at Centerville is on Middle Butte Creek 1½ miles west of Magalia, where it is crossed by a belt of tuff about 3,000 feet in width. In this vicinity the Mammoth shaft was sunk to a depth of 100 feet, and the Ethel tunnel was driven at an elevation of about 1,300 feet on the west side of Middle Butte Creek, but no satisfactory results were reported. Possibly the tunnel reached the channel at the point where it began to spread out.

The continuation of the channel is easily traced northwestward, Magalia being situated on the high southeastern rim, and it crosses Little West Branch 3 miles north-northeast of Magalia. In this canyon the tuff belt is about 4,000 feet wide and the rims rise sharply on each side. The Parry incline (fig. 6) is situated near the bed of the creek not far from its junction with West Branch, at an elevation of about 1,860 feet. The incline is sunk toward the west at an angle of about 22° from the horizontal, partly in bedrock, partly in tuff, and is 700 feet long, reaching a vertical depth of 260 feet, which makes the elevation of the supposed bedrock of the channel 1,630 feet. A drift 500 feet long was run, from which several raises 30 to 60 feet high showed that the channel was filled with coarse sand and large bowlders, with little pay gravel on the bedrock. The quantity of water pumped was naturally heavy and is given as 26 or 28 miner's inches. Below this point the Magalia channel continued in a narrow, canyon-like valley, widening to a more open one at Centerville. Although it traverses auriferous territory throughout, the results at the two places where it has been opened show that reliance

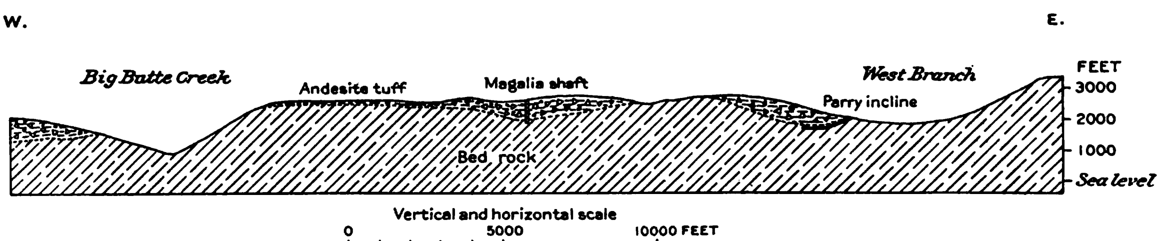


FIGURE 6.—Section through Parry incline and Magalia shaft from West Branch to Big Butte Creek.

can not be placed on its paying character. However, it should contain pay gravel, at least from the Parry mine downward toward the old Mammoth shaft. (See Pl. XIV, p. 84.)

The northward extension of the Magalia channel lies underneath the lavas on the west side of the West Branch. Its position is clearly indicated again where the Kimshew bridge crosses the West Branch[1] in the northeast corner of the quadrangle; the stream here flows over volcanic tuff for more than a mile at an elevation of about 3,200 feet, and the depth of the deepest channel covered by the tuff is unknown. East and west of this old canyon the bedrock rises sharply and abruptly almost 1,500 feet. The headwaters of this Neocene stream must lie in the southern part of the Lassen Peak quadrangle, and it crosses the northwest corner of the Bidwell Bar quadrangle.

PERSCHBAKER MINE.

The Perschbaker or Lucretia mine,[2] also called the Magalia mine, is one of the best-known drift mines in this part of Butte County. It is worked on a small tributary to the main Magalia channel, but has proved very rich in unusually coarse gold, which in places almost covered its bedrock. The total production is over $1,000,000. The mine is situated on Little Butte Creek 2 miles north of Magalia, at an elevation of about 2,500 feet. The first discovery was on the west bank of the creek; this was the old Perschbaker channel, which, as shown by figure 7, was followed down to the junction with a larger channel which above this junction seems to split, one of the branches possibly connecting with the Princess channel, 2 miles farther north. The main branch may be called the Little Magalia channel. The Perschbaker channel is a narrow and steep tributary, with a little angular wash and very coarse gold. Its grade is 282 feet in a total mined distance of 3,500 feet, in which it gradually decreased from 8 per cent to 3 per cent.

[1] Turner, H. W., op. cit., p. 546.
[2] Gassaway, A. D., The Magalia drift mine: Min. and Sci. Press, Apr. 8, 1899, pp. 372, 400.

The Little Magalia channel, mined for a distance of nearly a mile, falls 186 feet in that distance. The mining was done from a perpendicular shaft sunk 512 feet to bedrock, through "ash, lava, basaltic sand, and volcanic gravel." The flow of water was heavy, the maximum being 625 gallons a minute. At a depth of 452 feet the shaft encountered metamorphic gravel, which continued for 50 feet to bedrock. The wash in the Little Magalia channel is 50 to 60 feet wide, the pay gravel being 6 feet high from bedrock. The bedrock is slate, alternating with serpentine; one streak of limestone was crossed. Two faults were met, with sharp southern upthrows of 5 and 34 feet. The mine was idle in 1901.

The Princess (Aurora) mine[1] is located a mile north-northeast of the Magalia mine and is supposed to be working on an extension of the same channel. The inclined shaft is 330 feet deep, at an angle of 32°. The channel is said to be 70 feet wide and to contain 3 feet of blue gravel with large cobbles and bowlders and coarse gold on serpentine bedrock.

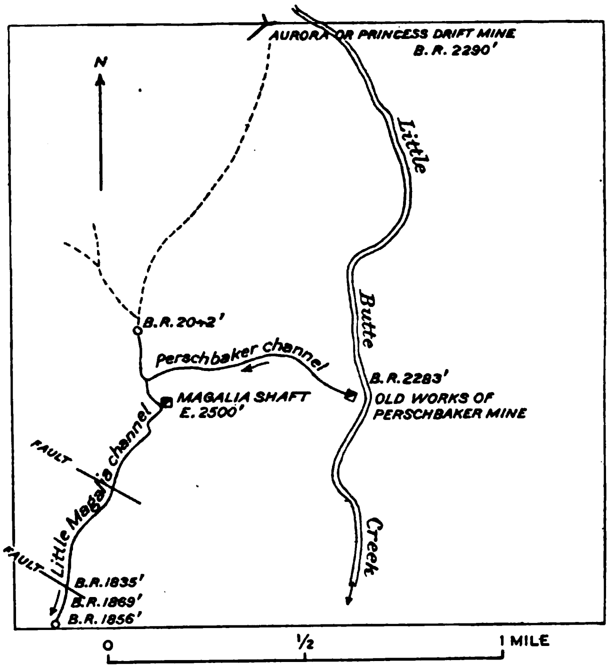


FIGURE 7.—Sketch map of the workings of the Perschbaker or Magalia mine.

EAST SLOPE OF BIG BUTTE CREEK.

A number of small steep channels have been found underneath the tuff cap along the east side of Big Butte Creek. (See Pl. XIV, p. 84.) One of them, northwest of Nimshew, called the Black Leg, was followed in a north of east direction for 1,200 feet. Another, the Emma, was followed for 1,670 feet from its outlet at Federal Point, a short distance southwest of Nimshew. The tunnel being long and crooked, a new 1,000-foot tunnel was driven in due west of Nimshew, at heavy sluice grade, the sluice being employed first to carry out the broken rock and later to wash the gravel. The gravel deposit is from 10 to 100 feet wide and from 1 to 3 feet thick and the pebbles are subangular and medium coarse. At many places andesitic tuff lies immediately on the bedrock. The grade of this channel for the distance worked is about 86 feet. The bedrock in the new workings is alternating slate and amphibolite, with one streak of limestone. Outside of the channel the bedrock seems to be covered by an old soil 1 or 2 feet in thickness. One tree trunk 10 inches in diameter was found standing upright in the tuff.

The Oro Fino mine is situated a few miles farther north, in Indian Springs Ravine, near Hupps Mill. Here a westward-trending channel has been followed up underneath the lava for about 2,700 feet. The gravel has a greatest width of 60 feet and is 4 feet deep, but in places the tuff closes down on the bedrock. The gold is very coarse. Underground hydraulicking is employed, as at Snow's mine in the Bidwell Bar quadrangle. A quarter of a mile farther north is the Indian Springs tunnel, which has followed a similar channel upstream in a northeasterly direction for 4,000 feet. This channel finally split in two, one branch trending toward Toadtown and the other going more to the north in the direction of the Pete Wood tunnel, owned by the Golden Gate Limited Co.

WEST SIDE OF BIG BUTTE CREEK.

Other small drift mines are located on the west side of Big Butte Creek, at Berdan and other places; also on the West Fork of Big Butte Creek, 6 miles northwest of Lovelock. They were not visited.

[1] Thirteenth Rept. California State Mineralogist, p. 91.

CHAPTER 6. THE BIDWELL BAR QUADRANGLE.

GENERAL GEOLOGY.

The Bidwell Bar quadrangle comprises the larger part of the main and most northerly block of the Sierra Nevada, which rises rapidly from the Sacramento Valley to elevations of over 7,000 feet near Spanish Peak. It has been deeply dissected by Feather River, some branches of which form magnificent canyons up to 3,000 feet in depth. The most striking features of the "Bedrock series" are several extensive areas of granitic rocks intrusive into greenstone, serpentine, and into less prominent belts of clay slates, which compose most of the Calaveras formation (Carboniferous).

Compared with adjacent quadrangles of which the geology is mapped, the Bidwell Bar quadrangle contains relatively small areas of the Neocene volcanic flows which were poured out over the old Neocene surface, and now, after Quaternary erosion, rest upon the ridge summits. In the northwest corner of the quadrangle are basalts, probably of about the same age as the general andesitic flows of the Sierra Nevada slopes. Along the Mooreville and parallel ridges in the southeastern part are basalt flows which antedate the andesite. Along the eastern margin, from Spanish Peak to Brandy City, are andesitic tuff-breccias in part resting upon the early basalt.

THE NEOCENE SURFACE.

In the absence of a general lava cover, the exact form of the Neocene surface is not everywhere easily traceable, although the more or less level ridge summits unmistakably indicate the moderate Neocene relief of the lifted block. According to observations in the country farther south, the prevalent granitic areas indicate that the Neocene surface was probably one of low relief. The Neocene surface appears to have formed undulating hills sloping southwestward, in which the streams had worn down valleys which were rarely more than a few hundred feet in depth. Northerly branches of the great Neocene Yuba River drained the southeastern part of the quadrangle; one of its headwaters probably came down from Cammel Peak by Davis Point, American House, Union Hill, Council Hill, and Brandy City, while a more westerly branch seems to have crossed the Mooreville Ridge from Ludlam to Dobsons, and thence, perhaps by way of Clipper Mill to Pittsburg Hill, found its way down, following the present canyon of the North Yuba.

Another channel, unquestionably flowing south, found its way from Gravel Range, in the Lassen Peak quadrangle, under Table Mountain to Snow's mine, its course south of that point being problematical.

In the northeast corner of the Bidwell Bar quadrangle the dislocations preclude satisfactory conclusions as to the direction of the channels.

DISLOCATIONS.

Faults were noted at Snow's mine, in the northwest corner of the quadrangle, trending northeast. None have been noted in the southeastern part, except two small ones observed by Goodyear at Brandy City.[1] Turner indicates a probable fault following Dogwood Creek and Bear Creek near the middle of the east boundary, and its continuation appears to have been felt in the dislocations at Laporte, in the Downieville quadrangle, but probably the downthrow on the east side did not exceed a few hundred feet at any place. The greatest displacement is that along the eastern slope of Spanish Peak, causing the deep depression of Meadow

[1] Whitney, J. D., Auriferous gravels, pp. 461, 462.

Valley, in the northeastern part of the Bidwell Bar quadrangle. The east side of the fault has evidently dropped 2,000 or 3,000 feet, for Neocene andesite-capped gravels rest on the very brink of Spanish Peak, while to the north of Meadow Valley they are found at elevations of 4,500 to 5,000 feet. Turner believes that the dislocation occurred just after the last andesite flows. Meadow Valley is thus a depressed area, and a lake was formed in it in early Pleistocene time. About the shores of the lake Pleistocene auriferous gravels accumulated,[1] and finally the lake found an outlet by way of Spanish Creek into the American Valley on the east.

PRODUCTION.

Most of the quartz veins in the quadrangle are short, and their pay shoots, with some exceptions, are small and pockety. The granite areas contain few veins of value, but the surrounding rocks are at many places fairly impregnated with gold-bearing veins and stringers. Forbestown is the most productive and permanent district, and its veins have fed both Feather River to the north and the gravel of New York Flat on the south. The western and northern edges of the quadrangle contain abundant pockets and veinlets. The gold recovered from the Snow gravel mine, on granite, seems to have been derived largely from the slates about Gravel Range. The gravels in the vicinity of Spanish Peak and Meadow Valley have proved rich, but there are few quartz veins of great productiveness. Along the middle of the eastern boundary of the quadrangle the gravels seem to have been less productive. The most important gravel deposits are found in the southeast corner, in the basin of the Neocene Yuba River. The hydraulic mines at Brandy City and Indian Hill have proved very productive, although there are no prominent quartz veins in the vicinity. The gold seems to have been derived from stringers and veinlets in the rocks. The large central part of the quadrangle is almost barren of gravels.

For the total production of the gravels of this quadrangle no exact figures are available. The total yield from the Neocene gravels does not approach that of the quadrangles adjoining on the south, southeast, and east. The canyons of Feather River were extremely rich, having received a very large amount of the gold accumulated on the Neocene surface in addition to that produced by Quaternary erosion. At present the production from drift and hydraulic mines is not large. A small output is reported from the Brandy City mines.

KIMSHEW TABLE MOUNTAIN.

In the northwestern part of the Bidwell Bar quadrangle is situated Table Mountain, a prominent remnant of an old basalt flow, whose summit reaches an elevation of 6,000 feet. It is at the head of Little Kimshew Creek, in Butte County, on the divide between West Branch and North Fork of Feather River. The creek mentioned was rich throughout, and was worked at Ramsey Bar in 1901. Snow's mine, which is currently credited with a production of $300,000, is situated at the southerly base of Table Mountain, but here a moraine almost entirely covers the Neocene gravels. The main branch of the stream probably comes down to Snow's mine under Table Mountain, with a southwesterly direction from the vicinity of Gravel Range and Lot's diggings, in the Lassen Peak quadrangle. A tributary from the Reese & Jones, Princess, and Butte King drift mines probably enters under the northwest edge of Table Mountain and should join the main stream underneath the summit.

At Snow's mine the valley of the Neocene river is partly preserved. On the west side rises a granite ridge, partly covered by moraine débris, to a maximum elevation of 400 feet above the channel in a distance of half a mile. On the east also high bedrock rises 500 feet above the channel. The old valley was thus about half a mile wide, so far as shown, and 500 feet deep. This channel was filled with gravel to a width of 100 to 200 feet and a thickness of 8 feet at most in the middle, thinning out toward the sides.

The gravel is very well washed, siliceous pebbles being extremely smooth. It rests on somewhat uneven soft granite bedrock, and contains some granitic sand. Practically all the pebbles,

[1] Downieville folio (No. 37), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

which range up to 1 foot or rarely more in diameter but are mostly smaller, are of quartzite, slate, greenstone, and some quartz. Above lies basalt or black clayey basaltic tuff, locally separated by a smooth surface from the underlying gravel. As noted above, almost the whole of the deposit is covered by a moraine—a heavy, in places partly cemented mass of coarse lava and granite bowlders.

This channel is cut by faults, apparently running northeast and southwest, into blocks, which in a rough way show on the surface; in one cut there is even a suggestion that some of the faulting may be postglacial, but the exposure is scarcely conclusive. In general there seems to be a series of steep faults dropping the channel southward.

The uppermost bench, the elevation of which is about 5,330 feet, was found on the east side by hydraulic work up a ravine (from Snow's old house) in the morainal mass. At the elevation mentioned the granite bedrock dropped off abruptly and on this rim was found rich channel gravel, which was sluiced underground for several hundred feet until a serious cave occurred.

Large's tunnel (elevation 5,340 feet) first cut through moraine to granite bedrock in 200 feet. Then a raise of 20 feet was made and in a short distance channel gravel was found below the moraine. The channel seemed intact and is covered in the usual way by basaltic tuff, partly also by basalt. Along one side of the channel is a sharply cut bench 4 feet high, not faulted. At a point farther north, several hundred feet from the entrance, Snow's northernmost breast was passed. At the end of the present drift, which runs northeast, is noted a sharp fault, vertical and striking northeast. The drop is on the northwest side, the black lava joining the gravel on that side.

Below this upper level is another, at an elevation of 5,175 feet, opened from Snow's old camp by a bedrock tunnel. It is said that several hundred feet of channel are breasted on this bench.

Still lower is the fragment opened by the tunnel and incline from a point near Little Kimshew Creek. The elevation of this working is 5,110 feet at the lowest point reached. A tunnel several hundred feet in length was run in granite northward. After breaking into the rim the bedrock was followed down for a vertical depth of 46 feet. There was a little gravel on the rim, covered by basalt. Near the bottom of the incline excellent pay was struck, but the extent of this streak was not ascertained on account of water. A tunnel was started in the moraine in the creek to tap this bench. The gold is worth $18.25 an ounce.

It is somewhat remarkable that this channel cut in the granite contains so little granitic sand. It is present only to some extent as a cement for the pebbles, but rarely in separate banks. This seems to indicate that the bedrock was either hard or perhaps more likely covered by thick vegetation.

In contrast to this the flat modern valley at Ramsey Bar in Little Kimshew Creek, also in granite, shows a thickness of 6 to 8 feet of granitic sand. The pebbles of metamorphic rocks in the Neocene channel were unquestionably derived from the metamorphic areas north of Table Mountain.

The Jones mine is about 3 miles north of Snow's diggings. In going up to it one ascends the basalt capping 200 feet above Snow's mine, follows a ditch on the west side of Table Mountain, and crosses the glacial basin of Crane Valley Creek, at the head of which the Jones mine is situated.

On the west side of Table Mountain underneath the basalt there is a distinct depression, indicated by bedrock rising several hundred feet on the north and about 200 feet on the south. The actual channel is hidden by lava sliding from the bluff above and by morainal débris. Some wash gravel is said to have been found at this point, which undoubtedly marks the inlet of a channel.

The Jones mine is located at an elevation of 6,000 feet, in a depression between granite knobs rising to 6,300 feet on the southwest and 6,500 feet on the northeast, about a mile apart. This channel was not indicated by placers leading up to it, nor was any gold found close by the outlet. It was discovered simply from bedrock indications; a small shaft was

sunk where gravel was supposed to be and within 25 to 40 feet struck the bottom of the channel with good pay.

The channel is worked in a small way by the Jones Brothers. One tunnel is run in for 1,200 feet, seemingly in part on the west rim. The bedrock rises somewhat and is a hard, uneven contact-metamorphosed slate. In one place the basalt closes down on bedrock and there seem to have been narrows or falls. Another tunnel only a few hundred feet long is located about 200 feet northeast of the first, at about the same elevation, and is the one which now is being worked. At this place gravel was found almost at the grass roots. The channel is from 75 to 100 feet wide, and the gravel, which is up to 5 feet thick, consists mostly of slate pebbles in subangular fragments, some of them 1 or 2 feet in diameter. Very little smooth wash is visible. The gravel is well cemented and the gold is mostly coarse.

Three-fourths of a mile to the north, in Last Chance Gulch, is another depression covered by Bracken & Doyle's claim, and closely adjoining is the tunnel of the Butte Princess Co. Near by is the Butte King mine, in which many years ago a rich channel descending steeply southward was mined by expensive methods.

The Butte Princess tunnel is about 1,500 feet long, and in its first few hundred feet penetrates the high slate rim. When the channel was reached the tunnel proved to be 15 feet too high. This channel has partly cemented, subangular slate wash like that of the Jones mine. The gravel has a width of 75 feet and is directly covered by lava; its thickness is at most 10 feet, thinning out on the rims. The bedrock is uneven and hard. The gold is coarse, flat, and in places rusty; many pieces of a value of about a dollar were found. At 1,200 feet from the mouth a tributary comes in, which is followed for several hundred feet north with rapidly rising bedrock. At one place there is a sharp fault, rising 20 feet at an angle of 30°. This face is covered with gravel like the rest of the channel, and in the gravel is some smooth wash.

A mile northeast of the Princess is the Westcott, which probably is on the same channel and somewhat higher.

Three miles a little east of north of the Princess are Carr's diggings, separated from Westcott's by a ravine. It is a mile north of Westcott's, at an elevation of about 6,200 feet, and carries quartz wash, partly subangular. The gravel is 20 feet thick and covered by lava. The channel probably trends northwestward.

The main channel which runs northeastward from Snow's and crosses Rock Creek probably reappears at Gravel Range and at the small diggings named Cash Entry, Lots, and Morris, which are situated at elevations of about 6,400 feet. A short distance north of this the elevation of the lava contact falls to 6,000 feet and the great lava fields of Lassen Peak begin.

From all the facts it appears that this channel system was situated near the summits of a moderately high range. The valleys of the watercourses were 300 to 500 feet and even more below the top of the ridges. The hills were probably covered by thick vegetation, preventing any great accumulation of débris. The valleys were flat, U-shaped, or bowl-shaped and contained gravel only along narrow beds 75 to 100 feet wide.

The covering basalt was evidently erupted shortly after the main andesitic flows. It is clear that it is much older than the basalt of Prattville, in the Lassen Peak quadrangle, the flows of which follow the present canyons. It is also certain that the channel which extends in an upstream direction northeastward from Snow's to the head of Rock Creek was the main channel, having a fall of only 70 feet to the mile, while the Jones channel has a grade of 200 feet to the mile.

Carr's diggings were probably on the northward slope of the Neocene divide. Thence down the distances and elevations along the principal channel are about as follows:

Westcott, elevation 6,200 feet, distance 1 mile, grade 45 feet to the mile.
Butte Queen, elevation 6,155 feet, distance three-fourths of a mile, grade 207 feet to the mile.
Jones & Reese, elevation 6,000 feet, distance 1½ miles, grade 267 feet to the mile.
West inlet, Table Mountain, elevation 5,600 feet, distance 1½ miles, grade 173 feet to the mile.
Snow's mine, elevation 5,340 feet.

On the other hand, the grade from Snow's to the head of Rock Creek is only about 70 feet to the mile. The grade is locally disturbed by faults, as clearly shown at the Snow mine, where the whole channel is sunk by step faults southward, and the possibility that the channel grade is increased by faults must not be overlooked. In all probability, however, there is little faulting above Snow's.

In looking southward from Snow's the high and fairly level ridge southeast of North Fork of Feather River is a noticeable feature. Between this ridge and Snow's are a series of lower ridges, seemingly indicating a sunken area, near whose northern rim the mine is located. No quartz veins were noted in the granite area, while several prospects and large veins occur in the slate adjoining on the north; probably most of the gold came from these slates.

NEOCENE GRAVELS OF MEADOW VALLEY.

Owing to Neocene faulting it is not possible to trace satisfactorily any channel system in the vicinity of Meadow Valley and Spanish Peak. On this peak Neocene gravels underlie andesite at elevations of 6,400 to 7,000 feet, and it is possible that the stream which deposited them may have drained southward and formed the headwaters of the most westerly branch of the Neocene North Yuba, eventually connecting with Brandy City.[1] The extent of the gravels of Spanish Peak is not great. The deepest depression, which contains a little gravel, is covered by about 40 feet of pipe clay, from which good plant impressions, said to be of Miocene age, were collected. The clay is covered with the same thickness of gravels, in part containing andesite pebbles,[2] and these detrital beds are covered by the usual tuffaceous andesite breccia.

To the northwest of Meadow Valley and about 2,000 feet lower are several smaller Neocene gravel patches, as shown in the Bidwell Bar folio.[3]

Two miles northwest of Spanish Ranch, at an elevation of about 4,600 feet, is the hydraulic mine of Bean Hill, which, according to unpublished notes by Turner, contains quartz gravels of the oldest prevolcanic epoch. Two miles north of Spanish Ranch, underneath a heavy capping of andesitic tuff, is the Pine Leaf channel, which has been traced in a northwesterly direction for about a mile. This channel is 200 feet wide and its gravels, which are only 4 feet thick, are stated to contain about $1.50 in gold to the cubic yard. They are covered by sandy pipe clay, above which lie masses of volcanic gravel. The channel has been worked at the Pine Leaf and Kniewel mines; the Kniewel tunnel, 1,100 feet long, is at an elevation of 4,900 feet and proved 40 feet too high.

QUATERNARY GRAVELS OF MEADOW VALLEY.

The downthrow of Meadow Valley, which is believed to have taken place at the close of Neocene time, created a lake, according to Turner, which finally overflowed and connected with the similar structural depression of American Valley to the east. Many gravel deposits that were formed in Quaternary time around the margin of this lake remain near Meadow Valley and farther east, on the north side of Spanish Creek, between Meadow Valley and Quincy. Turner[4] describes them as follows:

> The gravel beds about Meadow Valley * * * underlie the valley and form terraces about it, some of which attain an altitude of more than 4,000 feet, the lowest part of the valley having an altitude of about 3,700 feet. As has been before intimated, this valley appears to have been formed by orographic causes, probably in early Pleistocene time. The gravel beds that form the terraces about it plainly show that it was occupied for a long time by a body of water, and a glance at the topography shows that this lake must have drained easterly—that is, into the American Valley, itself an old lake bed, although apparently a shallow one.
>
> The Meadow Valley gravels have been mined very extensively by the hydraulic method at Gopher Hill, 1¼ miles east of Spanish Ranch. The banks now exposed show the character of the material finely. The exposure on the south side of the flume shows a vertical bank about 150 feet high, in which are two layers of a light-buff color from 1 to 5 feet in thickness. The lower layer is perhaps from 40 to 60 feet above the bedrock and the upper layer 50 feet higher. The same material is exposed in a bank north of the flume, and a specimen was taken there. Microscopic examination

[1] These gravels are described by J. D. Whitney in "Auriferous gravels," p. 216.
[2] Turner, H. W., Bidwell Bar folio (No. 43), Geol. Atlas U. S., U. S. Geol. Survey, 1898.
[3] Also described by Goodyear in Whitney's "Auriferous gravels," p. 474.
[4] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 556-558.

shows this to be composed of isotropic, translucent grains, often reddish by discoloration, and doubly refracting grains and angular particles, some of which are probably quartz. The isotropic material is probably volcanic glass. * * * The presence of the glass particles shows that these layers may represent in part volcanic ashes, perhaps from the Lassen Peak volcanic vents. The material is very light and friable.

The general color of the Gopher Hill gravel is reddish, a dark red near the surface. The pebbles are usually small, from 1 to 4 inches in diameter, and by far the greater number of them are flattened. Decomposed lava pebbles were noted, but the pebbles are mostly composed of rocks of the pre-Tertiary formations, quartzite, greenstone, and siliceous argillite being represented. Pebbles of white quartz occur, but are not abundant. There is a large amount of silt and sand, perhaps one-half of the entire material. Lying about over the area that had been washed by the hydraulic method were noted many well-worn pebbles about a foot in diameter, but there were very few of these to be seen in place in the banks.

A large surface of the lower gravel beds at Grub Flat and vicinity has been mined over. Underlying the well-rounded gravel northwest of Grub Flat is some decomposed "cement" gravel, made up largely of small round red, brown, and white particles, between which there has been an opaque white secondary substance deposited in concentric layers. Under the microscope this is seen to be a distinct tuff, but decomposed. It is made up of microlitic and glassy fragments in which the outlines of the feldspars are still to be seen. Some fragments contain fresh augite and hornblende grains, and there are also grains of serpentine present. Some of the particles are thoroughly rounded.

Along Wapanse Creek some of the lake gravel is subangular. Three and a half miles east of Meadow Valley post office, on a branch of Slate Creek, at an altitude of over 4,000 feet above sea, is some gravel with angular blocks of the late doleritic basalt like that capping Clermont Hill. [Some of these gravels were formerly mined. The camp was probably the one called Hungarian Hill.—W. L.] Four miles southeast of Meadow Valley post office, on the ridge west of Deer Creek, is some Pleistocene gravel, reaching an altitude of 4,700 feet, and a gravel area west of the South Fork of Rock Creek attains an altitude of 4,500 feet. There are also gravel beds that have been mined by the hydraulic method on the ridges east and west of Whitlock Ravine. [These mines were known as Badger Hill and Shores Hill. The gravels may represent portions of a deposit formed at a former outlet of the Meadow Valley Pleistocene lake.—W. L.] These gravels are like those at Gopher Hill. There is little doubt that all of these isolated gravel patches were originally connected with the large Meadow Valley area of lake gravel, although some of them may have been formed by Pleistocene streams draining into the lake, and some of them may have attained their present altitude by displacement subsequent to the lake period. The rocky barrier between Meadow Valley and the American Valley has been cut through by Spanish Creek in late Pleistocene time, and thus the lake was drained.

The production of placer gold for 1909 in the northeast corner of the quadrangle was distributed about as follows: Belden, $1,900; Bucks, $2,800; Meadow Valley, $2,100.

SOUTHEASTERN PART OF THE BIDWELL BAR QUADRANGLE.

Little definite information is available regarding the Neocene gravels on Mooreville Ridge and on the parallel ridges to the north. They are not extensive, nor do they seem to have been very rich, and their connection with known channel systems is very doubtful. Turner[1] says:

The Dodson gravel mine lies about 3½ miles northwesterly from Strawberry Valley, at the south border of the basalt flow that caps the Mooreville Ridge. The gravel is from 30 to 100 feet thick, and is largely coarse, but there is fine material in places. The pebbles are of granite, andesite, basalt, quartz, and metamorphic rocks. They vary in size from small pebbles to large bowlders, all well waterworn. A considerable amount of finely preserved silicified wood is found here. Prof. Knowlton determined this as being coniferous wood (*Araucarioxylon*). The basalt capping the mine is from 15 to 30 feet thick and shows a columnar structure in places. Some of the basalt pebbles contain crystals of chabazite in cavities. The bedrock is granite. Ludlam's hydraulic mine is, without much doubt, on the same channel as the Dodson. It lies on the north edge of the basalt of the Mooreville Ridge, about 4 miles a little west of north from Strawberry Valley. It differs in no essential particulars from the Dodson mine. The bedrock is granite. The gravel attains a thickness of about 90 feet and the basalt capping a thickness of about 150 feet. The lower gravel is chiefly made up of the older sedimentary and associated igneous rocks of the Auriferous slate series, and the upper part of Tertiary lavas. Fine silicified wood occurs here also. There is gravel on the Mooreville Ridge 2 miles northeast of Ludlam's mine. Under the basalt of Kanaka Peak there are well-rounded pebbles of the kind noted at the Dodson mine. At Walker Plain there are gravel beds under the basalt. The gravel of this channel at the Buckeye House is much like that at Kanaka Peak and the Dodson mine, so far as examined. While it is not probable that all of the gravel deposits under the older basalt belong to the same period, most of them are similar in containing some pebbles of Tertiary volcanic rocks and of the older rocks of the auriferous slate series and without doubt were formed by rivers of later age than those of the white quartz gravel period.

* * * * * * * * *

At the point called Clipper Mill, on the road to Strawberry Valley, is a long streak of Neocene river gravel about 600 feet wide. The pebbles are chiefly of the older siliceous rocks. There is no volcanic material associated with this area. At the west end of the andesite breccia area, or about 1¾ miles east of Clipper Mill, is a small deposit of gravel

[1] Op. cit., pp. 562, 564.

known as the Pratt drift mine. About 1½ miles north of Clipper Mill is the Gentle Anna gravel mine. The tunnel had evidently cut the olivine basalt that caps the deposit before it struck the gravel, which is half rounded and does not appear to represent a large channel.

The Clipper mine gravel, which lies in a sag a few hundred feet in depth on the summit of the ridge north of the North Yuba, at an elevation of about 3,500 feet, had some connection with the small body of partly volcanic gravel which is preserved at Pittsburg Hill, on the point south of the river and at a similar elevation. A small hydraulic mine was worked at the latter locality.

The gravels of the Sweetoil diggings, at the head of Dogwood Creek, were probably in some way connected with those of Little Grass Valley and La Porte. The bedrock elevation is about 4,600 feet, and the narrow trough filled with gravel is covered by some basalt, and above this several hundred feet of andesitic breccia.

The great La Porte channel, practically the West Fork of the Neocene North Yuba (fig. 8, p. 108) traverses the southeast corner of this quadrangle. The main channel comes down from the Poverty Hill inlet of Scales diggings and reappears at the Rock Creek outlet, continuing thence to Union Hill, Fairplay, Council Hill, Brandy City, Indian Hill, and Depot Hill (in the Smartsville quadrangle). The small gravel patch at American House probably represents a small tributary lying in a sag 800 feet above Slate Creek. The old valley is still shown by the bedrock rising several hundred feet on the east and west of the gravel. The deposit is of little importance. On the divide between Slate Creek and Canyon Creek, at Poverty Hill, a large curve of the Neocene channel is preserved and has been extensively hydraulicked. Considerable amounts of drifting ground probably remain. The channel was a well-defined trough about 500 feet deep and from 1 to 2 miles wide. The upstream continuation of this important channel toward La Porte is described in the chapter on the Downieville quadrangle (pp. 102–113). The deepest trough is filled with 10 to 30 feet of strongly auriferous and in places cemented "blue" gravel with large bowlders of quartz and slate. Above this lies a wide body of fine quartz gravel up to 120 feet in thickness. Above this gravel rests a stratum of soft volcanic ash or tuff, which again is capped by several hundred feet of the ordinary andesitic tuff-breccia.[1] Most of the gold is naturally concentrated on the bedrock.

In 1906 and 1907 the gravels of Poverty Hill were prospected with a view to drifting operations. The deep channel is about 150 feet wide. The gravel is only a few feet thick and along the rims thins out to less than 2 feet. It is covered by sand. The gold, which is moderately fine, is distributed through a thickness of 5 or 6 feet and the gravels are said to average $2 to the cubic yard. The lowest 2 feet of gravel contains most of the gold, but the upper part also yields a considerable amount. The distances and grades of the channel between Camptonville, in the Smartsville quadrangle, and Poverty Hill are shown below.

Distances and grades of the La Porte channel from Camptonville to Poverty Hill.

	Bedrock elevation.[a]	Distance between points.	Grade.
	Feet.	*Miles.*	*Feet per mile.*
Camptonville	2,657		
Depot Hill	3,120	4	115
Indian Hill	3,217	1	97
Brandy City	3,500	2	142
Council Hill	3,963	5	93
Fair Play	4,133	1	196(?)
Scales (Rock Creek outlet)	4,253	1.5	80
Poverty Hill	4,563	4	75
American House	4,750	3	60
		21.5	

[a] Chiefly from Whitney's "Auriferous gravels;" determined by Pettee.

The average grade is about 100 feet to the mile. It is not believed that faulting has greatly influenced these figures. Small faults were noted at Brandy City by Pettee.

[1] Whitney, J. D., Auriferous gravels, pp. 454, 460. Description by Pettee.

Large hydraulic operations were carried on at the isolated deposit at Brandy City and at the large body of gravels at Scales until the opposition to this kind of mining stopped work about 1891.

The following notes on the Brandy City hydraulic mine are taken from an article by G. F. Taylor,[1] the superintendent:

The Brandy City property covers all of the channel between Canyon Creek on the north and Cherokee Creek on the south for a length of about 2 miles.

These deposits were first discovered and worked in the early fifties by the methods then in vogue. Water could only be had in limited quantities and the local supply was soon controlled by a few persons who sold it at high rates. Then the Hoosier flume, 9½ miles long, was built from Canyon Creek and water sold for 25 cents per miner's inch. Work was carried on under great disadvantages until the Brandy City Mining Co. obtained control of the water rights and most of the claims.

The channel has a width of pay gravel varying from 300 to 700 feet, and there are about 10,000,000 cubic yards yet to be mined. The bulk of this lies at the northern end of the claims. The gravel here has a thickness of about 150 feet, with an overburden of 60 feet of cement lava (andesite breccia). The gravel to the depth of 130 feet is composed of small quartz pebbles ranging in size from walnuts to 3-inch pebbles. The lower 20 feet consists of cobbles and bowlders of quartz, granite, and other rocks up to 2 feet in diameter, mixed with finer material. The whole of this bottom stratum is so tight and compact as to require blasting to loosen it for washing. The bedrock is slate. Aside from the overlying lava ash, the whole deposit is pay gravel carrying near the surface about 10 cents in gold per cubic yard, and near the bedrock as high as $2.50 per cubic yard. In the spring of 1909 about 30,000 cubic yards of the upper part of the gravel was hydraulicked and 10 cents per cubic yard recovered. This gravel came from the east rim of the channel, 60 feet above bedrock. The general average of the gravel is estimated, from the old records, as 25 cents per cubic yard.

The Brandy City Mining Co. owns the entire water supply of Cherokee and Canyon creeks. Two ditches bring water from Cherokee Creek to the mine. One ditch is 5 miles long and has a capacity of 800 miner's inches; the other 3½ miles long, with a capacity of 500 miner's inches. The Canyon Creek water is brought to the mine by means of a flume and ditch about 9 miles long, with a capacity of 2,000 miner's inches.

As the company is operating in a field under the supervision of the United States Débris Commission, storage for the débris or tailings from the hydraulic operations must be provided. In this case there are old hydraulic pits which make admirable storage reservoirs for the detritus. These pits with the dams across their outlets provide storage for 6,000,000 cubic yards. As these pits contain no natural streams, they require but inexpensive dams to hold back the tailings.

The mine is provided with an electric plant, and during the coming season it is expected that at least 2,000 cubic yards of gravel per day of 24 hours will be washed. The flume to carry the tailings into the Arnott pit is 900 feet long, with a grade of 4 inches in 12 feet. It is 4 feet wide and 4 feet deep. The Boyce pit will be utilized later. The flume to convey the tailings to this pit is 6,000 feet long, 4 by 4 feet, with a grade of 2½ inches in 12 feet.

The cost of mining 500,000 cubic yards of gravel per year is estimated as follows: Labor, 40 men, 9 months, $32,400; labor, 10 men, 3 months, $2,600; engineering and superintendent, $3,000; powder, $8,000; raising and maintaining debris dams, $2,000; coal, tools, and incidentals, $2.000; total, $50,000.

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[1] Eng. and Min. Jour., June 4, 1910, p. 1152.

CHAPTER 7. THE DOWNIEVILLE QUADRANGLE.

GENERAL GEOLOGY.

As mapped by Turner, the principal geologic features of the Downieville quadrangle are as follows:

The Calaveras formation (Carboniferous) occupies the larger part of the western half of the quadrangle and is characterized by clay slates of steep dip and northwesterly or northerly trend. The sedimentary rocks of this formation are intruded by a complex dike of gabbro, peridotite, and serpentine, which is several miles wide in some places and extends along most of the west margin of the quadrangle, crossing into the Bidwell Bar quadrangle a short distance southwest of Quincy. South of the Downieville quadrangle it traverses the whole of the Colfax and part of the Placerville quadrangle. It is generally known as the Serpentine belt. An important area of granitic rock extends into the Downieville quadrangle from the south, but terminates south of the North Fork of the Yuba.

An important and almost continuous belt of old and partly altered augite andesite is intercalated in the slates of the eastern part of the quadrangle, and along it may be found smaller areas of highly altered Triassic strata (Milton formation). East of this the granitic rock of the higher Sierra begins and occupies almost the whole eastern margin of the quadrangle except in the northeast corner, where it is covered with andesite and other Neocene lavas. Smaller granitic intrusions exist at Indian Hill and the Scales diggings. A very prominent dikelike mass of partly schistose quartz porphyry extends from Sierra City to Johnsville, and a similar dike occurs in the Grizzly Mountains.

The Tertiary andesite tuff at one time probably covered the entire quadrangle except the high bedrock ridge extending in a north-northwest direction up toward the Grizzly Mountains and Houghs Peak. The remnants of this great lava sheet are found on nearly all the high ridges, separating the maze of canyons which characterize the southwestern part of the quadrangle. The eruptive centers were located near Mount Fillmore, Mount Ingalls, Grizzly Peak, and Haskell Peak.

DISLOCATIONS.

Neocene dislocations, possibly in part post-Neocene, are numerous in this area. A great fault follows Mohawk Valley, the downthrow on the east side amounting to 2,000 or 3,000 feet. Its northerly extension is obscure; probably one branch continues due north on the east side of the Grizzly Mountains, and another branch connects with the dislocations surrounding American Valley, which doubtless is to be considered as a "graben," or sunken block. An extension of the Dogwood Creek fault line of the Bidwell Bar quadrangle is noted at La Porte, but the throw is moderate. Smaller dislocations are common in the region between La Porte and Mount Fillmore.

No evidences of faulting appear along the southern margin of the quadrangle south of Downieville.

GOLD-BEARING AREAS AND PRODUCTION.

Gold is present in nearly every square mile of the metamorphic area, but the granitic rocks along the eastern margin and the Neocene lavas are practically barren. The central slate area and the old augite porphyrite of the Grizzly Mountains are relatively poor in gold. The most

extensive mineralization and the richest gold deposits are found along the great serpentine belt; wherever this is crossed by the old channels they are almost invariably rich. At the same time there is a marked absence of important quartz mines and the gold seems to be contained in small veinlets and stringers, chiefly along the contacts of the serpentine belt. A second auriferous belt of very great value follows the dike of quartz porphyry from a point south of Sierra City for 15 or 20 miles northward up to Johnsville. In this belt there are many celebrated quartz mines, among which may be mentioned the Keystone, Sierra Buttes, Young America, Empire, and Plumas Eureka. No Neocene channels cross this belt.

There is no way of accurately measuring the gold production of this area. Millions on millions of dollars worth of gold has been washed from the present river channels and the Neocene gravels in the southwestern part of the quadrangle west of a line drawn from Downieville toward Quincy. Compared to this yield that of the eastern quartz-mining belt is small, although the Plumas Eureka and Sierra Buttes mines have together yielded many million dollars. The Sierra Buttes mine alone is said to have produced $15,000,000.

Some approximation of the gold taken out from the enormously rich Slate Creek basin has been attempted by Pettee,[1] who estimates that the total amount of gold sent from La Porte, the principal shipping point for this region, from 1855 to 1871, was at least $60,000,000. To this a liberal amount should be added representing the gold obtained before 1855 from the present river beds. Pettee estimates that the annual yield of the Slate Creek basin about 1877 was $1,000,000. The closing of the hydraulic mines about 1885 reduced this amount heavily.

In 1905 the production of gold reported from the quadrangle to the United States Geological Survey was $244,000 from quartz mines and $143,400 from placer mines. The placer gold mined in 1905 and 1909 was subdivided approximately as follows, a considerable part of it being derived from tailings in the creeks and from surface operations on a small scale:

Placer gold obtained in Downieville quadrangle, 1905 and 1909.

	1905.	1909.
Plumas County:		
Johnsville	$7,000	....
La Porte	18,000	$32,000
Gibsonville	6,600	
Mohawk	1,200	1,000
Nelson Point	4,000	3,000
Quincy	4,000	2,600
Eclipse	....	6,500
Sierra County:		
Downieville	34,000	17,000
Sierra City	20,000	2,000
Gibsonville	6,000	22,200
Port Wine	3,600	1,000
St. Louis and Table Mountain	28,000	26,700
Scales	11,000	6,800
Total	143,400	110,800

The lower gravels in the principal channels are apt to be rich, ranging from $2 up to $20 or more to the cubic yard. Pettee cites a bank of gravel at La Porte, 250 by 100 feet and 30 feet high, that yielded at the rate of $20.87 to the cubic yard. Doubtless most of the gold was obtained near the bedrock.

A large amount of ground suitable for hydraulic work still remains in the western part of the Downieville quadrangle, although it is not much more than the quantity that has already been washed. The Army engineers reporting on the débris question make the following estimate,[2] to which it is proper to add that much of the gravel remaining is probably of lower grade than that already worked.

[1] Whitney, J. D., Auriferous gravels, p. 449.

[2] House Ex. Doc. 267, 51st Cong., 2d sess., 1891, p. 83.

Hydraulic gravel in basin of North Fork of Yuba River.

[Cubic yards.]

District.	Excavated.	Remaining.	
		Available at present.	Ultimately available.
La Porte and Spanishtown	10,400,000	800,000	800,000
Gibsonville and Whisky Diggings	2,500,000	500,000	500,000
Howland Flat and Pine Grove	1,850,000	1,375,000	1,375,000
St. Louis, Greenwood, and Grass Flat	8,600,000	2,850,000	7,850,000
Port Wine Ridge	1,600,000	500,000	1,000,000
Poverty Hill	2,250 000	4,000,000	5,000,000
Morristown Ridge	5,000,000	100,000	300,000
Scales and Mount Pleasant	4,050,000	30,000,000	60,000,000
Brandy City	10,800,000	6,600,000	6,600,000
Grizzly Hill	1,300,000	900,000	900,000
Eureka North, Poker Flat, Chaparral Hill	20,000,000	1,400,000	1,400,000
Monte Cristo, Chaparral Hill, Craycroft	2,000,000	500,000	800,000
Downieville, Sierra City, City Six, Loganville	1,200,000	500,000	800,000
Oregon Hill and Bullard Bar	900,000	400,000	400,000
Indian Hill	4,500,000	8,000,000	8,000,000
Willow Creek, Camptonville	5,800,000	3,600,000	3,600,000
	82,750,000	62,025,000	99,325,000

THE NEOCENE SURFACE.

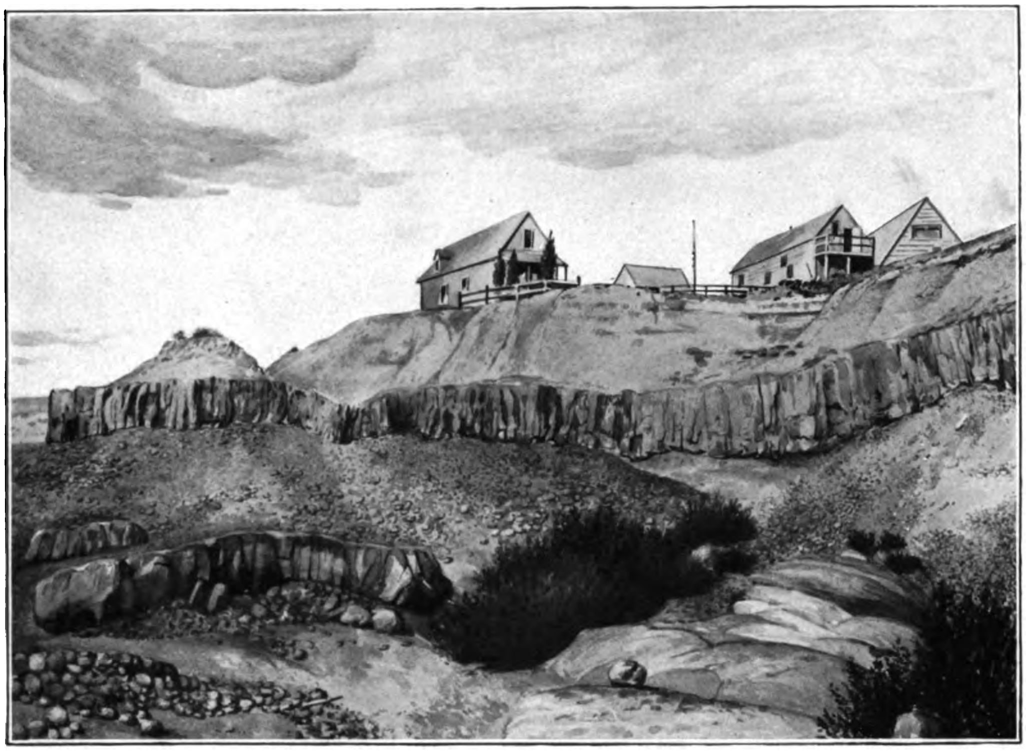
The Neocene topography of the Downieville quadrangle, so far as it can be determined by a study of the contacts of gravels and lava with the "Bedrock series," was one of decided relief. The broad uplands were furrowed by river valleys having a depth of several hundred feet or more. Many of the auriferous channels worked were clearly mere ravines or gulches with steep grade and subangular wash. The areas of metamorphic rocks were in general characterized by stronger relief than those occupied by granite.

An important ridge, prominent even now, after complex faulting and deep erosion, traversed the quadrangle in Neocene time, dividing the westward drainage of the old Yuba River from a large northward-trending stream, which has no modern equivalent. This watershed is marked by Sierra Buttes (Pl. XVIII, *A*, p. 134) and the high ridge which extends north-northwest from it, with a present elevation of 7,000 to 8,000 feet, and which, interrupted by the modern canyon of Middle Fork of Feather River, reappears in the north under the name of the Grizzly Mountains. The relations of lava and bedrock east and west of this ridge indicate a comparatively rough relief, and the absence of heavy accumulations of gravel confirms this conclusion. This Neocene divide was probably only partly covered by the lava flows and tuffs.

The principal stream, which may be called the west fork of the Neocene Yuba, is easily traceable from Hepsidam and Gibsonville down to La Porte, Scales, and Indian Hill; during the later part of the gravel epoch it was filled with fine quartz gravel to a depth of 100 to 130 feet and a width ranging from 1,000 feet to a full mile in places, but the hills still rise steeply above this flood plain. Branches of this river occupied the present basins of Slate and Canyon creeks. The main Neocene river is cut off by the present Feather River canyon, but it is not likely that it extended much farther to the northeast; the Neocene divide was not far distant. There are, moreover, indications that a downthrow has taken place in the region northeast of Hepsidam.

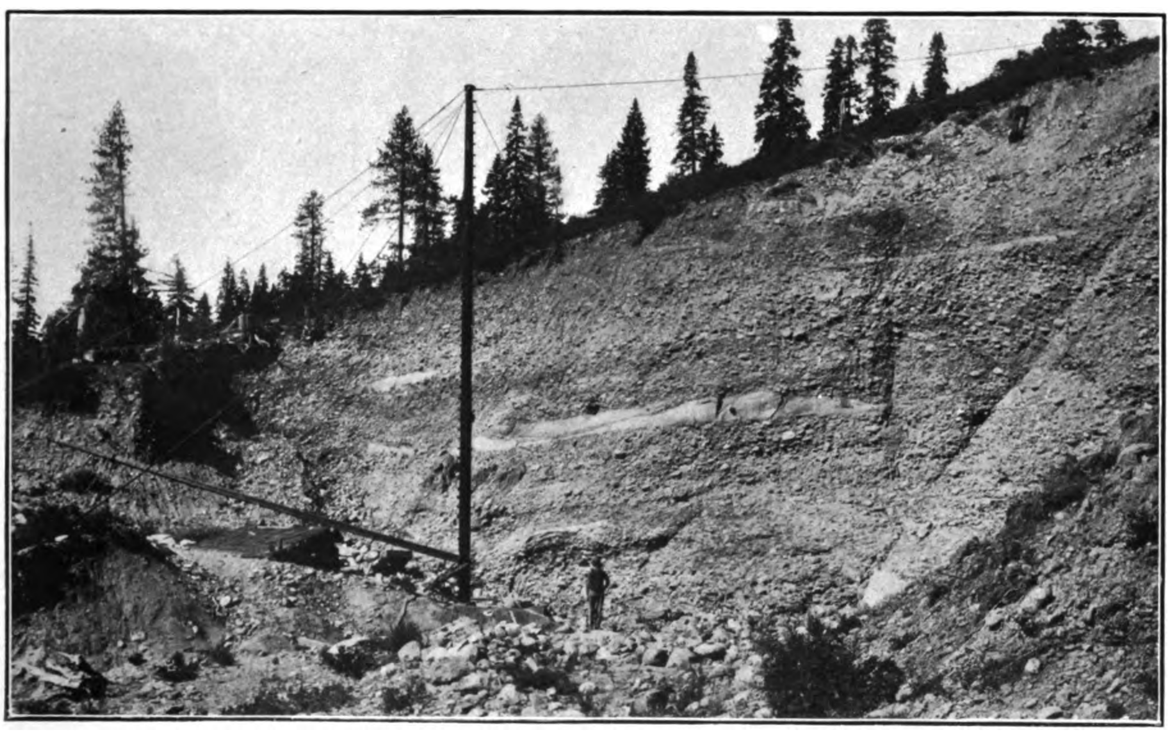
The small streams along the southern margin of the quadrangle flowed southward to join another branch of the Neocene Yuba. Along the eastern margin a mountain stream came down from Meadow Lake by way of Milton, and probably continued northward by way of Chips Hill and Haskell Peak, beginning to accumulate gravels from Chips Hill on. The great dislocation following Mohawk Valley caused a downthrow of at least 2,000 feet, and we find the northerly continuation of this Mohawk channel in a deep valley along the eastern foot of the Grizzly Mountains on its way to the waters surrounding the Neocene northern foot of the Sierra Nevada, in the Honey Lake quadrangle.

The study of the present grades of these old rivers, as set forth below, furnishes most valuable clues to the dislocations and deformation suffered by the Neocene surface.



A. BASALT SHEETS INTRUDED IN TERTIARY BENCH GRAVELS, PORT WINE, SIERRA COUNTY.

Bedrock in foreground. After photograph by Waldemar Lindgren. See page 108.



B. CASCADE DRIFT MINE, PLUMAS COUNTY.

Showing lowest gravels of Jura River. See page 112.

About the headwaters of Slate and Canyon creeks important volcanic eruptions of andesite, andesitic tuff, and basalt took place. The observer finds many places where masses of basalt have been intruded in the gravels, and several examples are cited by Turner and Pettee. An excellent illustration of this is furnished by a hydraulic bank at Port Wine, a photograph of which is reproduced in Plate XVII, *A*. It shows an irregular sheet of basalt which has been injected in the fine quartz gravel some 20 or 30 feet above the bedrock.

Gravels composed almost wholly of volcanic pebbles and representing the latest fluviatile deposits of the Neocene epoch are found in smaller amounts at several places, as the Scales diggings, La Porte, Bells Bar, Spring Garden Ravine, and the American Valley. But these can not readily be connected with definite river channels, and most of them are poor in gold.

MAIN CHANNEL FROM HEPSIDAM TO SCALES.

In the description of the Bidwell Bar quadrangle (p. 100) the main channel is traced from Poverty Hill at Scales down to Camptonville, with an average grade of 100 feet to the mile, the smallest grade, 60 feet to the mile, being recorded from Poverty Hill to the Rock Creek outlet at Scales, where the channel has a general southerly direction and is filled with quartz gravel to a depth of 120 feet. A probable distance of 4 miles along Slate Creek carries it up to the Secret diggings, a small patch remaining on the northwest side of Slate Creek with the rim rising steeply behind it. A distance of about a mile carries it up from this place to the lower end of the La Porte diggings, which have a north-northwesterly direction and are 1½ miles long, the bedrock having been uncovered for the whole of that distance.

From La Porte to Hepsidam the channel is deeply covered by andesitic tuff and clays, the total distance being about 10 miles. The greatest thickness of the volcanic covering is 800 feet. Much mining has been done on this ridge, stimulated by the known richness of the channel. The bedrock is mainly amphibolite, with some serpentine between Gibsonville and Hepsidam and a narrow belt of clay slate at La Porte.

At the Dutch diggings, at the northwest end of the La Porte gravel area, the main channel, as exposed, is about 500 feet wide with sharply rising rims. On the southwest side the amphibolite rim rises several hundred feet probably without being influenced by faulting. The northeast rim also rises sharply, as shown by the fact that bedrock appears on the main ridge along the road northeast and southeast of Bald Mountain, several hundred feet above the diggings, in spite of the fact that, as shown below, the channel has suffered a downthrow between these exposures and the Dutch diggings. The banks show 80 feet of almost clean quartz gravel even next to the bedrock there are few cobbles over 6 inches in diameter. Above the gravel lie 50 feet of sands and clays, the latter partly carbonaceous, rather evenly stratified, and conformable upon the gravels. Above the clays is the heavy cap of andesitic tuff. The gold was practically on the bedrock or in the gravel within 2 feet of it. What gold is contained in the upper gravel is fine and flaky. The Halsey bore hole, 2 miles north of La Porte, is evidently in the channel and shows the following section:

Log of Halsey bore hole near La Porte.

	Feet.
Surface lava	26
Hard gray lava	119
Clay	10
Black lava	120
Volcanic sand	2
Lava	39
Quartz gravel	8
Quartz gravel	90
Gravel and clay	14
Gravel	2
Gravel and clay	10
Quartz gravel	5
Bedrock.	

The gravels here are 129 feet thick. Near the Clay Bank tunnel, half a mile southeast of La Porte and probably at the rim, there was only 14 feet of gravel, covered by 167 feet of clay. Above this clay lies in places a heavy body of gravel with many pebbles of andesite and basalt, representing a later intervolcanic channel. In this region, however, these intervolcanic channels did not have time to cut down to bedrock, as on the Forest Hill divide and at many other points to the south, and the gravels are barren.

Up toward the Thistle shaft the clays increase in thickness to 300 and even 400 feet; to a large extent they are undoubtedly volcanic mud. Five bore holes sunk by the Feather Fork Gold Gravel Co. in 1899 and 1900 showed the following sections:

Sections of bore holes of Feather Fork Gold Gravel Co.

No. 1, July, 1899, 100 feet vertically above collar of Thistle shaft.

	Feet.
Lava	100
Clay, upper portions mixed with lava	95
Pure pipe clay	5
Small white quartz gravel	2
Sand, small and rough, mixed with clay	8
Pipe clay	180
Pipe clay and sediment	10
Clay sediment and bed rock	15
	415

No. 2, August, 1899

Lava	190
Pipe clay	169
Quartz sand	12
Pipe clay	279
Bedrock, soft at first, then hard	50
	700

No. 3, at Thistle shaft.

Pipe clay with streaks of quartz sand	380
Fine gravel	18
Pipe clay	11
Gravel, fine at first, gradually becoming coarser, until regular bowlders were struck; last 20 feet solid bowlders (6 to 21 inches)	63
Bedrock	5
	478

No. 3 (?).

	Feet.
Lava	130
Pipe clay	42
Blue sand	37
Pipe clay	141
Blue quartz sand	36
Clay sand with much wood	61
White quartz gravel and sand	14
Pipe clay	5
Quartz sand	4
Tough pipe clay	80
Quicksand, coarse sand, and gravel	25
	575

Great abundance of charred wood. Enormous flow of water in last 25 feet. Hole stopped owing to impossibility of driving casing any farther.

No. 4 (?), July, 1900.

	Feet.
Lava	72
Pipe clay	218
Quartz sand mixed with pipe clay	10
Pipe clay	80
Charred wood	6
Pipe clay	134
Quartz sand, gravel, and bowlders; heavy bowlders near bottom	70
Bedrock	10
	600

Similar conditions prevail between Gibsonville and Hepsidam. At the Thistle shaft, 5 miles above La Porte, the channel was 1,500 feet wide, with sharply rising rim, the east side being especially steep. At the Niagara mine, at Hepsidam, the channel was 800 feet wide between rims; of this a width of 500 or 600 feet was drifted. The gold on the bedrock was coarse, but the upper gravels in places contained pay. The tenor of much of the drifted ground was $3 a cubic yard.

This great channel has been mined almost continuously from Gibsonville to Hepsidam by means of tunnels. Between Hepsidam and Bunker Hill, a distance of about a mile, the Niagara Consolidated Co. has mined it by drifting operations extending from 1875 to about 1895. Near Bunker Hill the channel emerges, overlooking the Feather Canyon, and its continuation has been destroyed by erosion. South of Gibsonville the Feather Fork Gold Gravel Co. has mined it successfully from the Thistle shaft for a mile upward, the channel having been pumped dry at great expense. In 1901 a tunnel was completed a few miles farther down, about 2 miles northeast of La Porte, and the channel which had previously been approximately located by bore holes was mined with good success for some distance upstream. Lately, however, it is

reported that the channel was found to widen out to such an extent as to considerably lower the tenor of the gravel breasted.

A study of the grades of this channel develops many points of the greatest interest. As shown above, the grade from Poverty Hill up to La Porte was fairly even and averaged 100 feet to the mile. Above La Porte evidences of very serious disturbances are present on every hand. A fault zone which is at least 1 mile in width and which has a general northwest direction crosses the channel at La Porte, the total downthrow on the northeast side being probably 520 feet. The presence of faulting was recognized by both Pettee and Turner, although the full extent of the dislocation was scarcely realized. The first fault is seen in the exposed bedrock in the upper end of the La Porte diggings; the downthrow on the east side is 55 feet, and the gravel beds are bent over the fault scarp, which is nearly perpendicular. Further evidence is seen at the Spanish diggings, a detached body of gravel three-quarters of a mile southeast of La Porte, which is abnormally depressed 200 feet below the level of the old channel. The general direction of the channel was at this point parallel to that of the fault lines, and several slices have evidently been cut off and differentially dropped or elevated. The downthrow is 200 feet to the northeast, but there are at least two benches at intermediate elevations and a higher ridge or "horse" of slate separating the area of greater downthrow from that of smaller downthrow in the La Porte diggings. The Clay Bank tunnel has been driven for nearly 3,000 feet in a north-northwest direction to open a supposed channel in this vicinity. The elevation of its portal is about 4,800 feet. No gravels of value had been found in 1901, and it is indeed probable that only a fragment of the northeast rim, cut off by a fault, exists here. Possibly if the tunnel were continued several thousand feet farther it might encounter the other downthrown portion of the channel, as described in the following paragraph:

From the upper end of the La Porte gravel area, at the Dutch diggings, the channel was drifted northwestward for 500 feet, but at that point the gravel was cut off by a "wall" of "lava," which probably means andesitic tuff. These relations would suggest that a downthrow of the northeast side of at least 130 feet had been encountered, this being the distance from bedrock to volcanic covering at this point. There is little doubt that this is the continuation of the same fault zone which depressed the vicinity of the Spanish diggings at the southeast end of the gravel area.

The channel has next been traced at the Halsey bore hole, about 2 miles north of La Porte, in a gulch draining into Little Grass Valley at an elevation of 5,370 feet. The section (p. 105) indicates that the boring has penetrated into the deepest part of the channel; the bedrock elevation is 4,938 feet, or 118 feet below that at the Dutch diggings, about a mile distant.

About a mile farther up the ridge, in an east-northeast direction, the Feather Fork Gold Gravel Co. has opened the channel by a long tunnel, the elevation of which was determined on information derived from borings. The elevation of the bedrock here is 4,780 feet or 158 feet lower than at the Halsey bore hole. The channel has been successfully drifted for some distance upstream to a point where it widened out greatly, this spreading being accompanied by a lowering of the tenor of the gravel.

Two miles farther up the ridge in a northeast direction is the Thistle shaft, which was sunk some 20 years ago by the same company. The deepest bedrock at the shaft has an elevation of 5,030 feet, or almost exactly the same as at the Dutch diggings. From this point the channel has been mined upstream for some distance and proved very rich. The grade for a mile from the shaft, up to the line of the adjoining property, was 200 feet, the channel being reported as normal.

From this point up to Hepsidam the channel is easily accessible by tunnels, and has been almost continuously mined, the grade being throughout about 200 feet to the mile.

The property of the Niagara Consolidated Mining Co. is located 2 miles above Gibsonville, at the head of the North Fork of Slate Creek, and extends across the lava-capped ridge for about a mile in a northeast direction; the channel has been mined continuously underneath

this ridge. The same grade continues, and there are also as noted by Pettee[1] several sudden "jumps" amounting to 3 or 4 feet at a time. Pettee thought these represented rapids or falls, but it is much more likely that they are actual faults crossing the bedrock. When the writer visited the mine in 1887, the workings had advanced 3,900 feet under the ridge, the fall in that distance being 150 feet. Under the summit of the ridge a sudden drop was met, cutting off the gravel sharply and necessitating another tunnel 50 feet lower. This no doubt represents the beginning of a second fault zone, which has depressed the channel on the Nelson Creek side by at least several hundred or a thousand feet. This fault zone lies approximately in the extension of the Spanish Peak fault, but just how the two should be connected is doubtful, as no clearer evidence of dislocation is apparent in the space between the two breaks.

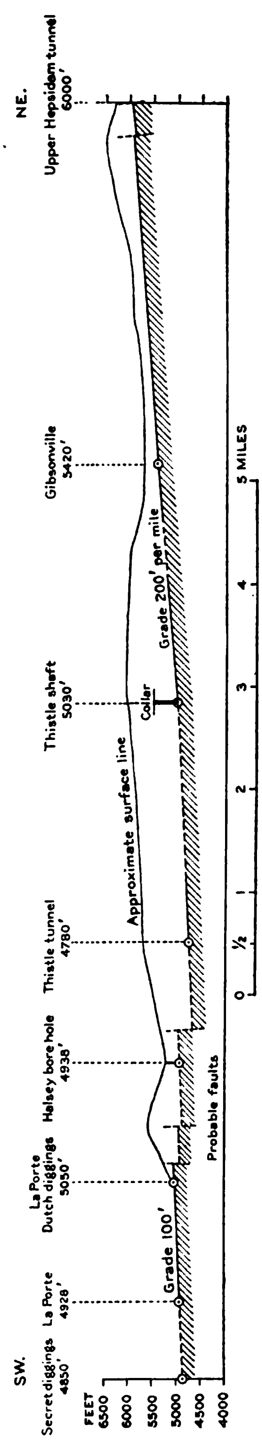


FIGURE 8.—Longitudinal profile from La Porte to Hepsidam, showing probable deformation of channel.

Figure 8 illustrates the relations described above. The even grade of the Neocene river below La Porte of 100 feet to the mile is replaced between the Thistle tunnel and Thistle shaft by a grade of 125 feet to the mile, and from the latter place to Hepsidam there is a long stretch of apparently even grade of 200 feet to the mile. These grades are undoubtedly much heavier than the original grade of the Neocene river. A well-marked fault zone crosses at La Porte, with a total northeastern downthrow of about 500 feet, and a similar or greater downthrow occurred northeast of Hepsidam. The deforming forces thus produced two zones of undoubted faulting and a sharp tilting of the block between them, amounting to something like 170 feet to the mile, allowing 30 feet to the mile as the original river grade. It does not seem likely that this tilting is the result of distributed faulting in a direction opposite to that of the two main fault zones, for the even and uniform grade would argue against this supposition. The elevations and grades along the channel are summarized in the following table:

Elevations of bedrock and grades of La Porte channel.

	Elevation of bedrock.	Distance along channel.	Grade per mile.
	Feet.	*Miles.*	*Feet.*
Poverty Hill (Pettee)	4,563		
Secret diggings (Pettee)	4,850	4	71
La Porte (lower end)	4,928	¾	104
La Porte (Dutch diggings) (Pettee)	5,050	1¼	98
Halsey bore hole	4,938	1	(a)
Thistle tunnel	4,780	1	(a)
Thistle shaft	5,030	2	125
Gibsonville (Pettee)	5,420	2	195
Hepsidam (upper tunnel) (Pettee)	6,000	3	193

a Fault.

PORT WINE CHANNEL.

As mentioned above, the main channel forks at Scales. The smaller branch is almost parallel to the main channel and lies only a few miles to the east of it. It was apparently separated from it only by a low bedrock ridge. The general course of this branch, which may be called the Port Wine channel, is by Mount Pleasant, the Iowa shaft, Bunker Hill, Port Wine, Queen City, Grass Flat, Gardners Point, St. Louis, Howland Flat, and Potosi. The quartz gravel is about 50 feet in depth, is well washed, and lies in a well-defined channel several

[1] Whitney, J. D., Auriferous gravels, p. 451.

hundred feet wide, with the rims of amphibolite rising several hundred feet above the bottom. Above the gravel are heavy masses of "pipe clay," above which lie andesite tuff and, in places, basaltic rocks.

Nearly 3 miles above the Scales diggings, at the outlet of Rock Creek, is the Iowa shaft; the elevation of the collar of this shaft is approximately 4,900 feet, and the elevation of the lowest bedrock found in the workings from it 4,582 feet. The shaft is a little over 300 feet deep, the gravel is cemented, and it is reported that $30,000 was extracted when it was worked about 25 years ago. The general opinion among miners is that a channel exists between the Iowa shaft and Bunker Hill, just south of Port Wine.

Turner [1] says:

To the northwest of Howland Flat and to the west of the road there are some fine exposures of the gravel beds, showing, by their irregular upper surface, that they were considerably eroded before being covered by the fragmental andesite. Mr. Ruep, who was formerly interested in the Howland Flat mines, states that a drift in the Hibernia gravel claim, 200 feet below the town of Howland Flat, came squarely up against a wall of compact lava like that forming the point on the ridge to the south known as Table Rock. * * * Mr. Ruep estimated that this drift struck the lava wall 1,700 feet below the summit of Table Rock and supposed it to be a part of the same mass as Table Rock. There was said to be 600 feet of pipe clay over the gravel at Howland Flat where not eroded. On the slope south of Table Rock, in a ravine draining into Canyon Creek, are the California diggings. According to Mr. Ruep only the lava wall of Table Rock separates this river gravel from that of Howland Flat, and if, as seems likely, the Deadwood gravel on the south side of Canyon Creek was formerly connected with the California diggings, the elevation of both being about 6,000 feet, this smaller channel may be regarded as a branch of the Howland Flat River [Port Wine channel]. The channel of Potosi (elevation about 5,600 feet) was followed in under the lava. At the time of Prof. Pettee's visit the continuation of the channel was not known, but he expressed the opinion that it extended under the ridge to Cold Canyon, on the slope toward Poker Flat. This has since been verified. The channel was followed in by tunnels. According to Mr. Ruep the gravel beds were much broken up, some masses being 50 feet above other masses. According to Mr. Lindgren there is said to have been a rise in the channel up to the middle of the ridge, then a fall, until at Cold Canyon the elevation is about that at Howland Flat. This rise and fall was not, however, gradual, but by steps, the channel being suddenly cut off at several points by polished and striated walls, evidently fault surfaces. The source of the channel east of Cold Canyon is unknown. Much and perhaps all of it is now eroded.

At Studhorse Canyon, below Cold Canyon, is a mass of detached gravel, which is possibly a displaced portion of the same deposit. The displaced character of the gravel is well seen at Bruckermann's tunnel [on the slope toward Poker Flat], where the gravel stratum stands in a highly inclined position. Between the gravel and the bedrock is a dike of fine-grained pyroxene andesite.

The Deadwood channel has been followed about 1 mile by tunnels in under the lava in a southeasterly direction to a claim known as Bunker Hill. Numerous faults are said to have been encountered in the tunnel, and at one point a large quartz bowlder is said to have been cut in two along a fault, so that one part was found in the roof and the other in the floor of the tunnel. Numerous lava dikes were met with. The course of this channel to the east of Bunker Hill is not known.

There are some gravel deposits that have been mined by tunnels on the east side of the high ridge of which Table Rock is a part, about east of Port Wine. This has been called the Wahoo district.

The Wahoo mine is opened by a tunnel driven in 700 feet due west from a point on this eastern slope. A small channel was found which was followed upstream with fair results for 1,300 feet in a general north-northeast direction. The gravel was not very wide and the pay was somewhat spotted. At the north end of the workings a 500-foot incline was sunk to a gravel deposit on the west side of the claim; this gravel, which rests on westward-pitching bedrock, probably connects with the Port Wine channel.

The Happy Hollow tunnel is run from the same east side of the ridge for 2,000 feet in a westerly direction and enters the Port Wine channel or a branch of it at an elevation of about 4,780 feet.

The following table gives the elevations along the Port Wine Ridge as determined by Pettee by mercurial barometer and aneroid; these are supplemented by some good aneroid measurements by the writer, but the determinations were not made with great precision and the figures are only approximate.

[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 602-603.

Elevations of bedrock and grades along and near Port Wine Ridge.

	Bedrock elevation.	Distance.	Grade.
	Feet.	*Miles.*	*Feet per mile.*
Scales, Rock Creek outlet	4,253		
Iowa shaft	4,582	3	110
Bunker Hill	4,850	2	135
Port Wine	4,853	½	(a)
Grass Flat	4,780	1	(a)
Gardners Point	4,845	1	65
St. Louis	4,993	1	148
Potosi	5,655	3	221
Cold Canyon	5,626	1	(a)
Deadwood	5,707		
Craigs Flat	5,100		
Morristown	5,160		
Eureka	5,000		
Monte Cristo	5,010		
Excelsior	5,020		
Craycroft	5,137		

a Fault.

This table indicates that the La Porte fault zone continues southeastward across the Port Wine Ridge, but with a diminished throw of about 200 feet. The bedrock at Gardners Point has almost the same elevation as that at Port Wine, 2 miles farther down the channel, and the bedrock at Grass Flat is nearly 100 feet lower than at Port Wine. Pettee [1] has reported the presence of a 50-foot fault in the workings of an old incline three-fourths of a mile above Port Wine. The downthrow was on the northeast side. The table further indicates a heavy increase in grade above Gardners Point and St. Louis, corresponding with that above the Thistle shaft on the La Porte divide. It is not probable that the fault zone between Potosi and Cold Canyon extended across up to the La Porte divide. The faulting in this region of volcanic activity seems to be of a very complex character.

OTHER GRAVELS WEST OF THE NEOCENE DIVIDE.

Few of the other gravel deposits in the western half of Downieville quadrangle can be connected into channels with any degree of certainty. Turner [2] briefly describes them, in substance, as follows:

A considerable river deposit has been extensively mined on the ridge east of Canyon Creek. It is well exposed at Morristown and Craig Flat. At the latter place the gravel shows evidence, by its very uneven upper surface, of having been eroded before being covered by the andesitic breccia. The large gravel mass at Eureka, 1½ miles southeast of Craig Flat, is undoubtedly a part of the same river deposit and lies in a gap with bedrock rising about 400 feet on each side in a distance of 1½ miles. The Eureka channel may thence be traced to the ridge east of Eureka Creek, where it has also been mined, and then across Goodyear Creek to the Monte Cristo and Excelsior mines. The course of the channel from this locality is a matter of pure conjecture. The drainage was probably from Monte Cristo to Eureka, as shown by the increased size of the gravel deposits in the direction of Eureka. From Excelsior to Craig Flat the direction of a channel would have been northwest. There is practically no grade from Excelsior to Eureka, and Craig Flat is 100 feet higher than Eureka.

On the summit of Craycrofts Ridge, east of Sailors Ravine, there are three patches of gravel. Underlying the alluvium of Little Grass Valley, 2 miles northwest of Bald Mountain, is a considerable body of white quartz gravel, which has been much exploited by means of shallow shafts. From its peculiar position, lower than the South Fork of Feather River, it has not been practicable to mine this gravel profitably on account of the water. This channel may continue under the Grass Valley Hill ridge and thence northeastward under the lava to Richmond Hill and Sawpit, northwest of Onion Valley. The white quartz gravel underlying Little Grass Valley is not all thoroughly rounded, and this is also true of the gravel at Richmond Hill and La Porte.

At the Richmond Hill hydraulic mine there is no lava on the gravel, but the extension of the same area to the east is covered by andesitic breccia, and on the east side of the breccia the Union Hill gravel mine is on the same channel. The Union Hill mine has also been worked by the hydraulic method. At Sawpit there is said to be white quartz gravel under the black basalt. If so, the deposit is undoubtedly part of the Richmond Hill and Union Hill channel.

About 2½ miles northwest of Onion Valley, on the north edge of the andesitic breccia area, on the slope toward the Middle Fork of Feather River, is an area of gravel on serpentine bedrock. Immediately west is an area of the older basalt, which extends lower down on the slope than the gravel.

[1] Whitney, J. D., Auriferous gravels, p. 456.

[2] Turner, H. W., op. cit., pp. 603 et seq.

There are a considerable number of remnants of gravel deposits besides those already mentioned, and Turner states that many of those which are described in the following paragraphs probably belong to the epoch of intervolcanic channels.

On the north side of the Middle Fork of Feather River, about half a mile west of Nelson Point, is a gravel deposit that was formerly mined by the hydraulic method. Andesitic breccia occurs on the slope to the north and presumably at one time covered the deposit. The occurrence is remarkable as being only about 200 feet above the present Feather River, at an elevation of about 4,000 feet. On the south slope of Clermont Hill, near the summit, at an elevation of about 6,400 feet, 4 miles west-northwest of Nelson Point, an English company exploited a gravel channel that is covered by andesitic breccia. The gravel seen by Turner at the mouth of the tunnel was chiefly of quartz and other siliceous rocks and was largely subangular in character, indicating a small watercourse. The gravel is said to have contained a good deal of gold in spots.

The New Nelson placer mine is situated 3 miles northeast of Nelson Point, on the slope of the high ridge overlooking Feather River, the tunnel having an elevation of about 4,500 feet. The channel opened by this tunnel has been followed under the volcanic cover for some distance in a northeasterly direction, and it is believed that it may connect with the gravels at Spring Garden, 3 miles farther to the northeast, or with the channel found in the tunnel of the Western Pacific Railroad near by. As the elevation of the gravels at Spring Garden is at least 500 feet lower than that of the placer mine on the Feather River side, it is probable that a fault intervenes, and such a fault is indicated on Turner's map of the Downieville quadrangle. It would represent the northward continuation of the Mohawk Valley line of dislocation and involve a considerable downthrow on the northeast side. In their present depressed position the Neocene gravels at Spring Garden can hardly be consistently connected with any known channel except as above stated.

On the steep east slope of the ridge, 4½ miles northeast of Johnsville, are some prevolcanic gravels. At Miller's tunnel, the altitude of which is about 6,500 feet, a gravel deposit has been found under the andesite capping of the ridge. The material seen is subangular and contains small fragments of blackened wood. The bottom of the Miller gravel channel is about 400 feet vertically under the top of the ridge. It evidently represents a small deposit of gulch gravel.

On the ridge north of Indian Valley and east of Canyon Creek are a number of gravel deposits at the edge of the large area of andesitic breccia capping the ridge. These may be parts of a single subordinate channel. The southernmost occurrence is at the Rocky Peak drift mine, about 2 miles north of Indian Village; the next is on the west side of the volcanic cap at Bunker Hill; another area is at the Sailor Boy diggings, and the most northern is just west of McMahons. The gravel at all these points is more or less similar, the pebbles being of dark quartzite, siliceous schist, and Tertiary lavas. At McMahons the lowest gravel consists chiefly of white quartz, the pebbles of which are usually 3 inches or more in length, and there are in addition the same pebbles as noted above. The elevation at McMahons is less than 5,000 feet, and the other masses noted lie at a successively lower level toward the south, so that at the Rocky Peak mine the elevation is only about 4,000 feet. The course of the channel is therefore probably southward. There is no likelihood of any connection of the gravel at McMahons with the large channel at Eureka, as higher bedrock intervenes, but it is not impossible that the McMahons channel may have joined that at Scales, although the character of the gravel indicates that it is part of the Sailor Boy channel.

Gravels occur under the fragmental andesite on the high ridge south of Downieville. They were mined by a shaft at the Pliocene mine and by a tunnel at the Ruby mine, north of Table Mountain, in a ravine draining into Rock Creek. Two distinct channels have been found. One, the older, extends toward the Bald Mountain Extension mine channel but is not certainly connected with it. The younger channel lies 116 feet lower and connects with the old Rock Creek diggings and with those at the City of Six. At the head of Slug Canyon is the City of Six gravel deposit. The material exposed is 500 feet wide and one-third of a mile long. The pebbles are of quartz and of the older metamorphic and igneous rocks. This channel was tunneled

through to Rock Creek. The channel of the Bald Mountain Extension mine has been extensively worked from tunnels that start in on the south slope of the ridge. The Nebraska diggings are on the north slope of the ridge, 2½ miles southeast from the Pliocene shaft, in the drainage of Jim Crow Ravine. The gravel, which extends under the andesite breccia, has been mined on a large scale. (See chapter on Smartsville quadrangle, pp. 121–132.)

GRAVELS EAST OF THE NEOCENE DIVIDE.

In the following paragraphs Turner[1] describes the remnants of the important stream which flowed north from Haskell Peak to a point in the Honey Lake quadrangle, where it evidently debouched into the Neocene gulf.

Commencing on the north we find north of the fortieth parallel (Honey Lake sheet), on the ridge east of Little Grizzly Creek, at elevations of from 5,500 to 5,800 feet, three masses of river gravels. South of the fortieth parallel (Downieville sheet) the gravel is first seen on two spurs of the Grizzly Mountains about 2½ miles southeast of Tower Rock. Two miles farther southeast, at the Cascade gravel mine [Pl. XVII, *B*, p. 104], the river deposits may again be noted, and immediately south of this mine is another gravel area that has not yet been mined. The average [bedrock] elevation of all these gravel masses is about 6,000 feet. * * * The thickness of this river deposit is about 325 feet. There are large granite bowlders in the gravel, which presumably came from the granite area immediately to the south. The bedrock of the mine is the auriferous slate series. * * * The occurrence of the granite bowlders to the north of their source, although but a short distance, may be regarded as evidence that the river drained to the north. Carbonized and blackened wood occurs in the gravel at the Cascade mine.

The two bodies of gravel last noted lie on the edge of the large area of andesitic breccia that forms the upper portion of the southern part of the Grizzly Mountains. There is little doubt that the channel extends under the lava and reappears on the south border of the area on the spur north of Little Long Valley Creek, where the elevation of the gravel is from 5,600 to 6,000 feet. The large area at the south end of this spur has been hydraulicked. Going south the gravel of this ancient river is next to be seen about Lava Peak, and then on the spur south of Long Valley Creek, some of the gravel at the latter locality having an elevation of only 5,000 feet. At the north end of the Mohawk Lake beds is an area of well-rounded gravels, composed of pebbles of the pre-Cretaceous rocks. This deposit rests, where surely in place, on the auriferous slate series. The low altitude (about 4,500 feet), of a portion of this gravel at the mouth of Cedar Creek is probably due to landslides, for where it is certainly in place on the ridge south of Cedar Creek the maximum elevation is 5,500 feet, extending down the ridge slope (easterly) to near the 5,000-foot contour. A tunnel by the Feather River at the mouth of Cedar Creek has been run in to strike this gravel channel, but if landslides have occurred here, it is evident that the tunnel is much too low (4,400 feet). The tunnel, according to a miner at work there, was 1,800 feet long in 1890 and was in hard lava all the way. The hard lava referred to is the andesitic breccia that forms the bed and walls of the river in this vicinity. A shaft was sunk on the hilltop 500 feet above and east of the tunnel's mouth. It is said that this shaft was in gravel for its entire depth, or 375 feet. As indicated above, however, all of the gravel below the 5,000-foot contour is believed to be out of place. This downthrown material is, however, not all gravel. There is some andesitic breccia mixed with it. Numerous rhyolite bowlders and pebbles indicate an area of that rock in the vicinity, now eroded or covered over. The presence of these rhyolite pebbles would seem to indicate that a portion of this gravel is of later age than that of the Haskell Peak channel, which is capped with rhyolite.

So far as could be made out, the Cedar Creek river gravel is in immediate contact on the south with the Pleistocene Mohawk Lake beds. The deposits of the old river channel just described, extending from north of the fortieth parallel near Little Grizzly Creek to the north end of the Mohawk Lake beds, are similar in being made up of gravel and coarse sand, with very little fine sediment. This may be taken as evidence that this river bed had a higher grade than those of the southwesterly system of the western half of the Downieville area.

The next gravel area to the east of the high Sierra Buttes is on the steep granite slope south of Mohawk Valley, where it has an elevation of 7,000 or more feet. A large portion of this gravel mass has, however, gravitated down the slope, and some of it lies at an elevation of only 6,600 feet. Overlying the gravel is rhyolite. This channel is next exposed on the rhyolite-capped spur 1½ miles north of Haskell Peak, where there is a layer of fine loose sediment overlying the gravel. * * * Among the pebbles in this deposit are many which appear to have been derived from the old tuffs of the Milton formation [(Triassic or Jurassic), exposed in the southeast corner of the Downieville quadrangle]. * * *

The next gravel bed to be described, that at Chips Hill, may be part of the same channel, for there the bedrock is the Milton series.

Chips Hill is on the south slope of the high ridge north of the South Fork of the North Fork of the Yuba River, 3 miles northeasterly from Sierra City. The elevation of the bedrock is about 6,500 feet. Rhyolite overlies the gravel and is in turn covered with andesitic breccia. Just east of the Chips Hill gravel is a prominent south spur of the main ridge, and on the east side of this spur is another body of gravel at the edge of a narrow area of rhyolite, and this gravel may be connected under the ridge with the Chips Hill gravel. This eastern mass of gravel has a granite bedrock.

[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 610–612.

The gravel about Haskell Peak is about 500 feet higher than that at Chips Hill, and if the drainage of this river was to the north it is plain that the Haskell Peak region has been differentially elevated. However this may be, the occurrence of a considerable body of river gravel on the edge of a high plateau, with a steep slope of more than 2,000 feet to the east and north, is very remarkable. There can be no reasonable doubt that a great displacement has occurred here. On the backbone of the ridge south of Sierra City, and about 3 miles southeast of that village, is a small amount of rhyolite, at the east edge of the large andesitic breccia area that caps most of the ridge. A little scattered river gravel is to be seen here, though it is obscured by the morainal material. The elevation is about 6,500 feet. It seems probable that here is a trace of the same channel as that at Chips Hill.

Two miles southeast of Milton is a very considerable mass of rhyolite lava, and on the west base of the andesitic breccia area that caps the ridge west of Tehuantepec Valley, 2½ miles east of Milton, is a long, narrow exposure of rhyolite. These rhyolitic areas may easily have been connected at one time and formed part of the flow that came down the Neocene basin to the east of English Mountain (Colfax sheet), and it is by no means impossible that this early Neocene drainage connected with that at Haskell Peak.

To this description by Turner it should be added that the present writer has mentioned the Meadow Lake-English Lake channel in another publication[1] but assumed then that it turned and flowed down the present Middle Fork of the Yuba to connect with the American Hill channel. As far down as English Lake this channel does not seem to have contained any large amount of gravel. The writer still believes that the drainage during the intervolcanic epoch had that direction, but it seems very possible that the early Neocene drainage continued parallel and to the east of the Neocene divide across the gap north of Milton and by Chips Hill to Haskell Peak and farther north. In that case the old stream bed has been considerably deformed, for the gap north of Milton has an elevation of over 6,100 feet; Chips Hill, as stated, reaches 6,500 feet and Haskell Peak 7,000 feet, while the elevation of the deepest point of the rhyolite flow between English Lake and Milton is only 6,000 feet. If the channel existed as outlined a sharp tilt must have taken place between Milton and Haskell Peak, reversing the grade. Then the channel was cut by the great Mohawk fault and dropped about 2,000 feet. From Mohawk Valley northward another reversal of grade, more gentle than the first, must have occurred. The stream flowed throughout in a deep valley, the sides of which rise in places over 1,000 feet above the channel.

QUATERNARY GRAVELS.

No detailed description of the auriferous gravels in the present stream beds will be given here. Most of them were worked out long ago, and the richest regions were those in which the Neocene channels have later yielded most.

Mention has been made of the early Quaternary gravels in Meadow Valley, in the Bidwell Bar quadrangle. Somewhat similar conditions prevailed in American Valley. Gravels are found several hundred feet above the present canyon of Spanish Creek, between Quincy and Meadow Valley, on the north side of the stream. American Valley was doubtless a lake for a short time after the dislocation at the close of the Neocene period. But an outlet was soon established and gravels indicating such an outlet are found 2¼ miles north-northwest of Quincy, near Elizabethtown, in a gap of the slate ridge separating American Valley from Blackhawk Creek. The bedrock elevation here is 3,800 feet; at Quincy it is 3,407 feet. These gravels correspond to a number of small remnants of bench gravels about 500 feet above the present bottom of lower Spanish Creek and East Branch. Subsequently this outlet was abandoned by the stream and two others were successively established farther west, the latest one being the present canyon of Spanish Creek at the north side of American Valley. In the gulch from Elizabethtown to American Valley fragmental deposits of two or three later channels are found, also auriferous and draining down toward the American Valley. The latest of these deposits is below the present creek bottom, at depths of 50 to 100 feet, and connects with gravels buried below the alluvium of American Valley. A shaft sunk in the valley a short distance north of Quincy encounters bedrock at an elevation of 3,171 feet, the elevation at Quincy being given as 3,407 feet. No rich gravel was found. Much information regarding these Quaternary channels has been collected by Mr. Watson, surveyor of Plumas County.

[1] Bull. Geol. Soc. America, vol. 4, 1893, pp. 257-298.

CHAPTER 8. THE HONEY LAKE QUADRANGLE.

GENERAL GEOLOGY.

The Honey Lake quadrangle embraces a square degree extending northward from the fortieth parallel and westward from the one hundred and twentieth meridian. No complete geologic map covering it has yet been issued, but its southern half has been mapped and described by J. S. Diller,[1] from whose account the following notes have been compiled. This contribution to the knowledge of the Tertiary gravels of the north end of the Sierra Nevada is of the greatest importance and completes in the most desirable way the results obtained by Turner and the writer in the central and southern parts of the range.

The most northerly areas of pre-Tertiary rocks of the Sierra cease near Susanville; north of this point the lava fields of the Lassen Peak region have completely covered the older formations. The fault scarp at Honey Lake delimits the Sierra on the east; this scarp and a belt extending for about 15 miles to the east is occupied by coarse intrusive granodiorite and quartz diorite; west of this and embracing the structural depressions of Indian Valley and Mountain Meadows begins a complicated belt, including sedimentary and igneous rocks of Paleozoic and Mesozoic age, the structure of which has been described by Diller in considerable detail. Late Tertiary andesites cover a large part of the granitic plateau south of Honey Lake and smaller areas overlie the Tertiary gravels of various ages which occupy much space between Susanville and Mountain Meadows.

DISLOCATIONS.

Faults of late Tertiary age are conspicuous at the north end of the Sierra. Most prominent is the Honey Lake fault, traced by Diller and undoubtedly continuous with the fault east of Reño described in the Truckee folio.[2] Near Honey Lake a throw of about 2,000 feet is indicated, which is considered to have taken place at the close of the Tertiary. The downthrow is on the east and the scarp facing that direction is one of the most distinctive shown in the range. Diller considers that this fault near Susanville passes into a monocline over which the Tertiary auriferous gravels are bent. For about 15 miles west of the Honey Lake dislocation the rocks have suffered little faulting, but the surface of the block appears to be tilted westward. West of this are several minor dislocations, along which valleys of subsidence have been formed similar to those of Meadow Valley and American Valley farther south. Most prominent among these are Grizzly and Indian valleys and Mountain Meadows; the fault scarps face northeast, like those of Honey Lake, but the dislocations are not long or continuous.

GOLD-BEARING AREAS AND PRODUCTION.

On the whole this region has proved less rich than the areas farther south. The principal belt of quartz veins extends from Greenville to Crescent Mills and Taylorsville, in a southeasterly direction. A less productive belt follows the granodiorite contact from Wards Creek on the south in a north-northwesterly direction to Lights Canyon, a distance of 15 miles. According to Diller the total production of the Cresent Mills belt is about $6,650,000, of which the larger part was derived from Quaternary placers. The Genesee belt is believed to have yielded about $450,000. At the present time placer mining is confined mainly to the Quaternary placers of Lights Canyon and Indian Creek. The total yield is about $10,000 annually.

[1] Geology of the Taylorsville region of California: Bull. U. S. Geol. Survey No. 353, 1908.
[2] No. 39, Geol. Atlas U. S., U. S. Geol. Survey, 1897.

Tertiary gravels have been mined about the head of Lights Creek, Mountain Meadows, and Moonlight for over 20 years, and their total yield is believed to be about $500,000.

A little placer mining has been done on Gold Run, a few miles south of Susanville. This is the most northerly place in the Sierra Nevada at which gold mining is carried on. In 1909 the placer production of the Honey Lake quadrangle scarcely reached $5,000. Most of it came from Seneca and Crescent mills.

THE TERTIARY TOPOGRAPHY.

In the bulletin mentioned Diller has shown that the drainage of this region during the Tertiary period flowed to the north and that the important river which Turner traced through the Downieville quadrangle east of the Tertiary crest of the Sierra Buttes and Grizzly Ridges continued northward until, between Mountain Meadows and Susanville, its deposits widened into large gravel areas marking the entrance of the stream into a wider valley or plain. Diller has named this watercourse Jura River, an appropriate designation which will be adopted in this description. In the Downieville quadrangle, north of the Mohawk fault, this river flowed in a broad and deep valley, whose sides rose 1,500 to 2,000 feet above the channel. The same characteristics are maintained in the southern part of the Honey Lake quadrangle. Above the Taylor diggings, in the high gap east of Indian Valley, Mount Jura rises 1,000 feet above the bedrock in less than a mile and the eastern bedrock ridges rapidly attain a similar height. The level bottom of Indian Valley is now under the combined influence of subsidence and erosion, 2,000 feet below the bedrock of the ancient channel. Few data are available to determine the precise character of the Tertiary surface west of Indian Valley.

From the Mount Jura gap the continuation of the ancient river is clearly indicated toward the gap separating Mountain Meadows from the drainage of Indian Valley; this is occupied by a heavy body of gravels which on the northwest side descend to the level of Mountain Meadows. On both sides of this gap the bedrock ridges rise to a height of about 1,000 feet. This place marks the end of Jura River, at least so far as definite exposures are concerned. The river undoubtedly followed the present Mountain Meadows for a few miles to the northwest; the depression of the old channel is clearly marked, even if the slope of its west side has been accentuated by later faulting. To the northwest of the valley Tertiary lavas cover the whole country. Diller believes that the river here emerged from its course in the mountains into more open country and holds that the great masses of well-washed gravels of Tertiary age which underlie the andesite between Susanville and Mountain Meadows were parts of the delta deposits of Jura River. The bulk of these gravels contain no late volcanic rocks and they carry but little gold.

These heavy masses of gravel continue to the southwest for about 12 miles, almost to the crest of the range and up to elevations of 7,000 feet, but the upper parts, to a great extent, consist of intervolcanic beds of Tertiary igneous pebbles. The faulting along the Honey Lake line has clearly affected their position with reference to Jura River, the channel of which lies at an elevation of only about 6,000 feet. It is suggested that in late Tertiary time, when the old outlet by way of Mountain Meadows was clogged, Jura River was forced to turn northward from Jura Gap toward Lights Canyon and Moonlight. The opinion of Diller that the high gravels southwest of Susanville have been bent over the north end of the Honey Lake escarpment has already been mentioned. About 7½ miles southwest of Susanville, near the head of Willard Creek, he found a number of plant remains, which are considered by Knowlton to indicate a late Eocene age and which, therefore, are the oldest flora known from the auriferous gravels. The other fossil leaves found in this vicinity—for instance, those near Moonlight and between Susanville and Mountain Meadows—are clearly of Miocene age.

Near the divide these gravels rest on a markedly uneven surface, the irregularities of which can not be attributed wholly to deformation and faulting. At Diamond Mountain the contact of volcanic gravel and granite lies at an elevation of 7,000 feet, while a few miles farther northeast, along the Susanville and Taylorsville road, the same contact has an elevation of only 5,500 feet.

THE GRAVELS.

The first remains of Jura River north of the fortieth parallel are at Ward's diggings, where three flat-topped masses of prevolcanic gravel rest at an elevation of 5,500 to 5,800 feet on the divide between Wards Creek and Little Grizzly Creek. A thickness of about 100 feet is exposed. The shingling of the pebbles indicates a northward course of the old streams.

Four areas of gravel are situated in the gap northeast of Mount Jura. The two largest of these have been mined at the Taylor and Hull diggings, but in recent years no work has been done here. The lowest bedrock has an elevation of about 5,500 feet. About 100 feet of coarse gravels are exposed; at the base of these lie beds of sand, and at one place a 500-foot stratum of impure lignite.

At the southeast end of Mountain Meadows the lowest bedrock is not exposed, but the gravels descend to the valley level of 5,000 feet. The reconcentrated gravels in the present gulches are mined at intervals on a small scale. On the Lights Canyon side the lowest bedrock is at 5,000 feet.

The large gravel areas around the head of Lights Canyon have a lowest elevation of about 5,000 feet and may thus at one time have been connected with those at the Jura Gap and at the head of Mountain Meadows. Near Moonlight the total thickness is over 1,000 feet; the upper 600 feet consists chiefly of conglomerates, the lower 400 feet of sands; their dip is about 20° NW.; the gravel is poor in gold, but some mining has been done in the lowest part of the gravels where they rest on the bedrock.

In the east branch of Lights Canyon the gravels have been prospected, and good values are said to have been found in bore holes which penetrate the covering andesite to a depth of 200 to 300 feet.

CHAPTER 9. THE SIERRAVILLE QUADRANGLE.

GENERAL GEOLOGY.

The Sierraville quadrangle covers one-fourth of a square degree and extends from the boundary of the Downieville quadrangle (longitude 120° 30′) on the west to the Nevada-California State line on the east; it adjoins the Truckee quadrangle on the north. The northeastern part of Sierra County, the southeastern part of Plumas County, and the extreme southern part of Lassen County are included within its limits. In the center of the area lies the flat depression of Sierra Valley, which is about 20 miles long from northeast to southwest and about 12 miles wide. On the west side the valley is drained by Feather River, whose uppermost headwaters it contains. Beckwith Pass, on the east, having the low elevation of 5,300 feet, lies only about 200 feet above the valley level and descends in about the same vertical distance to Long Valley, the first depression of the Great Basin. Irregular ridges and complexes of hills surround Sierra Valley, but in these the structural features of the Sierra Nevada find little expression. The highest points are in the southeastern area of andesite and reach 8,700 feet.

No detailed geologic work has been done in the area, but many parts of it have been visited by H. W. Turner [1] and the writer. H. C. Hoover examined the southern part in 1895.

Comparatively small areas of older rocks are contained in the quadrangle. Granodiorite is the prevailing rock of the "bedrock series" and forms the escarpment west of Sierraville and also the main escarpment from Beckwith Pass northward. This rock continues all the way to the vicinity of Susanville, about 40 miles north of Beckwith Pass. South of Beckwith Pass several small areas of metamorphic schists of uncertain age are exposed along the eastern escarpment, and a mass of pre-Tertiary and altered andesite or basalt forms the greenstone ridge in the extreme southeast corner of the quadrangle.

As stated before, almost the entire area consists of andesite, partly breccia, partly massive. The andesite is not present as stratified tuffs or tuff breccias, but the massive rock and the breccias are mingled in a way which leads to the belief that the rocks were erupted from numerous vents within the area of the quadrangle.

Only smaller areas of the Sierraville quadrangle have been covered by glaciation. The Quaternary plains of the Sierra Valley form one of the most conspicuous features of the quadrangle. Except at Beckwith Pass and near Sierraville this level valley is almost entirely surrounded by andesite. The valley is somewhat marshy in its western part, but elsewhere comprises agricultural lands of high productiveness. The sedimentary deposits filling the valley are of great depth. It can hardly be doubted that at a comparatively recent period, before the drainage through Feather River was established, the valley was occupied by a shallow lake. There are no higher beach lines surrounding the valley, except one at an elevation of 5,030 feet, about 130 feet above the general level of the valley, and this is not everywhere well developed and is in no place conspicuous. The best exposures are near Loyalton, where they are marked by some well-washed gravels. No prominent débris fans project into the valley, from which it may be inferred that the filling of the lake has proceeded rapidly.

A great number of artesian wells have been sunk throughout the valley and a flow of water is often obtained. The deepest well, as far as known, is at Callahan's, near the center of the valley, which penetrated 27 feet of gravel at the surface; underneath this the drill passed through 1,000 feet of "blue clay" and 200 feet of sand and clay. No bedrock was reached and the flow of water was hot. At several other places hot water has been reached underneath the deposit of "blue clay" at 700 to 800 feet below the surface. In one well, 5 miles north of

[1] Further contributions to the geology of the Sierra Nevada: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 655-656.

Loyalton, the temperature of the water is 80° F. Samples procured by H. C. Hoover indicate that the "blue clay" is probably an andesitic tuff.

It is likely that Sierra Valley has remained a lake from the close of the Pliocene to the latest Quaternary and that its basin contains underneath a thin covering of Quaternary gravels, deep accumulations of andesite tuffs of the same age as the andesites in the rest of the quadrangle.

It is clear that the lake has never stood at a much higher level than 5,000 feet. Had it been 200 feet higher at any time, an outlet to the Great Basin through Beckwith Pass would have been established.

STRUCTURAL FEATURES.

So far as known, there is no evidence of postandesitic faulting within this quadrangle, unless it should prove, on closer examination, that the late movement near Honey Lake extended to the latitude of Adams Peak. There are several preandesitic fault scarps, but they have been so extensively covered by andesite that they do not form conspicuous topographic features.

The first escarpment, continued from the fault line immediately west of Lake Tahoe, appears in the southwest corner 3 miles from Sierraville and within a short distance enters the Downieville quadrangle, forming there the conspicuous Mohawk Valley fault, along which postandesitic movement has taken place. The escarpment near Sierraville has been deeply cut into by erosion and has now a height of about 2,000 feet. Along the southern edge heavy andesitic flows have completely covered this slope and there is no indication of dislocations in this andesite.

The fault line following the eastern shore of Lake Tahoe enters the quadrangle in the southeast corner, but is almost immediately so heavily covered by andesite that its continuation is uncertain. It probably dies out before the northern part of the quadrangle is reached.

The main eastern fault line, continuing from the Carson and Truckee quadrangles, enters at the southeast corner of the quadrangle and is no doubt continuous in a northerly direction along the entire eastern boundary. Though partly covered by andesitic flows it presents when viewed from a distance a fairly even slope about 2,000 feet high. At Beckwith Pass it sinks to a height of about 1,000 feet. Farther north the scarp is very much higher and attains north of Adams Peak heights of 3,500 feet. It is not entirely straight, for at Adams Peak a salient projects several miles to the east, like the similar salient at Carson, about 50 miles farther south. The escarpment is entirely of granite and faces some low desert ranges across an intervening valley, which lies at elevations of 4,500 to 5,000 feet and is a few miles wide.

Sierra Valley would seem to offer an excellent opportunity of testing whether any very recent, late Quaternary deformation has taken place within this block of the Sierra. If tilting has taken place, the movement has been slight. A close observer, however, can not fail to be impressed by the marshy character of the valley near the west side, in contrast to the decidedly higher and dryer east side. It is believed that since the draining of the lake the surface has suffered a slight westward tilt.

Tertiary lake beds of doubtful age are exposed at a number of places along the railroad, which follows Long Valley in front of the main eastern escarpment. The beds are clayey and sandy, none being tuffaceous, and dip at angles of 20° to 30°.

MINERAL DEPOSITS.

No placers or quartz mines are known in this quadrangle. In the andesite east and southeast of Sierraville there are some areas in which thermal decomposition has developed.

CHAPTER 10. THE MARYSVILLE QUADRANGLE.

MARYSVILLE BUTTES.

ORIGIN AND PRESENT FORM.

The Marysville Buttes are the remnants of an extinct volcano of probably late Neocene age the internal structure of which is to a certain extent laid bare by erosion. In any view from a distance two distinct features of the mountain group are always noted—the peripheral slopes, reaching up to 600 or 700 feet in a long, gentle curve, and the abrupt and jagged interior peaks and domes. It is probable that when the volcano was in active eruption it formed one great cone, and that its original form can be reconstructed with considerable accuracy by carrying up the curves of the lower slopes, with gradually increased declivity, until they culminate in a summit high above the present peaks. The drainage is radial, the creeks and ravines originating in the central mass and flowing thence north, east, south, and west.

There are three divisions of the buttes, which are topographically and geologically distinct. They are the peripheral tuff ring, the interior ring of upturned sedimentary rocks, and the central core of igneous rocks.

THE TUFF RING.

The first subdivision corresponds to the gentle slopes mentioned above and is made up of a successive series of beds of mud lava poured out from the vents of the volcano. In its typical development this mud lava consists of gray or brownish-gray finely ground detritus in which lie embedded angular fragments of andesite or, more rarely, rhyolite of all sizes. Very commonly, however, there is more or less sedimentary material—clay, sand, or gravel—mixed with these mud lavas, or tuffaceous breccias, as they might be called. The abundance of this sedimentary material is explained by the loose character of the beds through which the eruptive masses must have forced their way. These mud lavas show a close analogy with similar enormous masses largely covering the flank of the Sierra Nevada. They were probably poured out as a semifluid, hot mud, and were only to a less extent the result of ash showers. Narrow gulches or defiles have been cut through this ring of mud flows, leading from crater-like valleys with level bottoms, many of which are of roughly circular shape and surrounded by steep walls of tuff or massive andesite.

The tuff slopes emerge from the Quaternary of the Great Valley at an elevation of about 150 feet, but scattered well-washed pebbles of quartzose, metamorphic, volcanic, and Neocene rocks occur up to an elevation of 300 or 400 feet, or to about the height reached by the Pleistocene lake or river sediments on the flank of the Sierra. No indications of terraces or shore lines are, however, visible; they are also absent on the Sierra Nevada side.

THE UPTURNED SEDIMENTS.

Between the exterior mud flows and the massive core, and strongly contrasting with them, there occur a series of smooth, rounded hills, forming an interrupted ring a mile or less in width. These hills are not of volcanic origin, but consist of a series of sandstones (usually soft), white or dark clays, and gravelly beds. As a rule they dip away from the central core, and where near it stand at high angles, locally vertical. At the intermediate contact with the massive volcanic rocks these sediments are usually hardened. No volcanic detritus of the same rocks of which the buttes are made up is found in them, and it may be regarded as certain that they were laid down before the period of volcanic activity.

The oldest of these formations belongs to the Tejon formation (Eocene); it has thus far been identified only in the sedimentary area northeast of the village of West Butte. Here it is composed of greenish sandstones and shales, adjoining the volcanic masses and dipping at high angles east or west. A thickness of several hundred feet of sediments is exposed. Some of the beds contain abundant marine fossils, characteristic of the Tejon, among which a small coral (*Trochosmilia striata* Gabb) is most abundant. *Cardita planicosta*, a form eminently characteristic of the Tejon, is also found.

Overlying these beds are light-colored soft sandstones and clays, dipping about 20° W., which have been referred to the Ione formation (Miocene). The other sedimentary areas consist largely, if not entirely, of these soft, light-colored beds. Near the tuffs they dip 15° to 20° S.; near the central volcanic mass they usually stand almost vertical. In many places the beds are greatly disturbed and dip in various directions within short distances. In the clays of these areas, in carbonaceous strata, impressions of leaves were collected. Marine fossils were found about 2 miles east of the South Butte and 2½ miles north-northwest of the South Butte. The fossils, while not abundant, point to a Miocene age. These beds are believed to be the exact equivalent of the Ione formation exposed along the foothills of the Sierra Nevada. Their aggregate thickness is very considerable, 1,000 feet being a fair minimum estimate.

The following fossils were identified by Messrs. Stearns and Dall:

Crassatella collina Conrad.
Venericardia borealis Conrad.
Verticardia? sp.
Acila castrensis Hinds.
Liocardium apicinum Carpenter.
Fusus (Exilia) sp.
Macoma sp.
Tapes (Cuneus) sp.
Saxidomis sp.
Cardium modestum.
Galerus sp.

THE CENTRAL CORE.

The central mass of the buttes consists principally of massive volcanic rocks, mixed with some breccias of the same materials. Most prominent, and occupying the largest area, are rough and jagged peaks and ridges of dark color, showing many beautiful columnar and laminated structures. They are made up of normal hornblende-mica andesite of very rough, trachytic appearance. Both the North Butte and the South Butte are formed of this material. Between these rough ridges are some smoother hills, consisting of mixed andesite and andesite breccia, with some rhyolite.

The eruptions took the form of large masses or necks, forced upward through the loose sediments. The mass and the energy of the ascending lavas were so great that the surrounding sediments were uplifted more than 1,000 feet and bent upward on all sides of the necks. It is probable that the ascending lavas were very viscid and comparatively cool, so that in some measure they acted as a plastic solid mass. The surrounding sediments, of which now a large part is probably erroded, prevented them from breaking out and forming lava flows.

The time at which the volcano was active can be fixed at the close of the Pliocene, or at the beginning of the Quaternary. It was probably a little later than the eruptions in the Sierra Nevada.

GOLD-BEARING GRAVELS.

Among the Neocene beds of the Marysville Buttes there are gravels of varying degrees of coarseness, some of the pebbles being 5 inches or more in diameter. The pebbles are well washed and consist of quartz, siliceous sedimentary rock, diabase, granite, and serpentine. All of this gravel, as well as the parts of the volcanic mud flows that contain a considerable mixture of gravel, are slightly auriferous, and many of the gulches and ravines in such areas have been washed during the wet season with some profit. The gold is well rounded and, as a rule, moderately fine. A few exceptionally large pieces, up to a value of $5, are reported to have been found. In some places these deposits might be profitably washed by the hydraulic process if it were possible to obtain sufficient water.

These coarse auriferous gravels are certainly a most interesting feature, occurring so far from their source in the Sierra Nevada. There are no indications of quartz veins in the buttes.

CHAPTER 11. THE SMARTSVILLE QUADRANGLE

GENERAL GEOLOGY.

Igneous rocks of the "Bedrock series" prevail in the Smartsville quadrangle, which reaches from the Sacramento Valley up to the region of the upper foothills—that is, to elevations of about 3,000 feet. Late Jurassic igneous rocks of basic character, variously classed as diabase, augite porphyrite, porphyrite tuffs, and where more altered as amphibolites, occupy the largest areas. In speaking of them collectively the name "greenstone" is most convenient. They include some narrow strips of the Calaveras formation (Carboniferous) and possibly also of the Mariposa formation. Large intrusions of coarsely granular rocks have been forced into these greenstones and consist of quartz diorites, granodiorites, and gabbros, the gabbros usually appearing as marginal facies.

The gravel areas are small, as are the areas covered by andesitic tuffs. The region is, however, of special interest because it is traversed by the lower reaches of the great Neocene Yuba River. A flow of andesitic tuff followed the river down to the plains and spread out in front of the foothills. The larger part of the quadrangle has never been covered by Neocene volcanic matter.

No Neocene or post-Neocene dislocations are known to exist within this area.

GOLD-BEARING AREAS AND PRODUCTION.

Gold-bearing veinlets and seams are so widely distributed through the "Bedrock series" that almost every creek has at one time been washed or prospected. The poorest areas are those of the central greenstone belt and the whole southern margin of the quadrangle. A fairly well-defined belt of stringers and short veins follows the amphibolite belt of the foothills from Albin Hill, near Spenceville, to Browns Valley and northward. Rich pocket veins occur near Rough and Ready, in Nevada County, and near Hansonville and Indiana Ranch, in Yuba County. Other veins of note are found in the upper amphibolite belt from Bullards Bar to Grass Valley. By far the most important quartz-mining district is that of Nevada City and Grass Valley, which annually yields a couple of million dollars or more.

The yield from the Neocene gravel mines at Nevada City and along the main Neocene river from North Columbia to French Corral has been very large. At present the production from this source is almost negligible, and the quadrangle does not contain any reserves of great value for future hydraulic or drift work, except at French Corral, Nevada City, Badger Hill, and Cherokee.

In 1908 the principal production was derived from dredging operations on lower Bear and Yuba rivers. The small placer mines of Yuba County yielded about $30,600 in gold. From Camptonville, French Corral, Nevada City, and Grass Valley drifting and sluicing operations yielded about $48,000. In 1909 the hydraulic mines near Camptonville (including Brandy City) yielded about $19,500, and the mines at French Corral, Grass Valley, Rough and Ready, and Smartsville, $8,000.

The Army engineers[1] estimate the amounts removed and available as follows:

Hydraulic gravel in basin of Yuba River.

[Cubic yards.]

District.	Excavated.	Available at present.	Ultimately available.
French Corral	32,500,000	10,000,000	10,000,000
North San Juan, etc	20,000,000	2,000,000	2,500,000
English Company	7,000,000	....	....
Badger Hill and Cherokee	10,000,000	1,000,000	33,000,000
Paterson	5,000,000	1,000,000	96,000,000
Sweetland, Birchville, etc	60,000,000	1,150,000	1,150,000
Rough and Ready and Randolph Flat	3,000,000	1,000,000	1,000,000
Nevada City (Sugar Loaf)	10,000,000	5,000,000	25,000,000
Murchie, Mayflower, etc., near Nevada City	500,000	1,000,000	3,000,000
Smartsville, Timbuctoo, and Mooney Flat	44,800,000	33,400,000	50,000,000
Sicard Flat	1,700,000	500,000	1,000,000
Keystone and Redjacket	10,000	....	20,000,000
Eastern Star and other claims below Timbuctoo	....	....	10,000,000

The measurements by G. K. Gilbert show that the volumes excavated are for the most part considerably greater than the figures here given.

Regarding the amounts available it should be stated that in many places the remaining gravels are poor, or, as at Nevada City, capped with so much lava that it would cost a great deal to work them, even under most favorable conditions.

As to the yield of the heavy gravels along the main stream from Smartsville to French Corral, few data are available, and most of those which follow are taken from Whitney's "Auriferous gravels."

The thick gravels from Cherokee to French Corral contain gold throughout; even the top gravels at Cherokee are profitable by the hydraulic method and yield 10 to 15 cents a cubic yard in fine gold. At American Hill, below North San Juan, the channel has been worked for 3,000 feet, the width from rim to rim being about 1,000 feet, the thickness averaging 150 feet. The gross product from 1860 to 1872 was, according to Whitney,[2] $1,241,240. Pettee says that the gravel averaged 30 cents to the cubic yard. The lower end of the San Juan Hill yielded $157,000 in 1858, the contents averaging 35 cents to the cubic yard. This includes the bottom gravel, which is much richer than the top.

The total yield of the Smartsville diggings up to 1877 is estimated by Pettee to have been $13,000,000; the average yield was probably 37 cents a cubic yard.

EXTENT OF WORKINGS.

The almost continuous deposits from North San Juan to French Corral have been worked throughout their extent, and large parts of these areas are now exhausted; much gravel still remains, however, at French Corral. The maximum depth of these gravels is 250 feet. At Badger Hill, the outlet of the Big Columbia and North Bloomfield channels, and at Paterson extensive hydraulic mining has been carried on. The gravels are here 300 to 400 feet deep, and, except at Badger Hill, bedrock has not been exposed in the center of the channel, nor have any drifting operations been undertaken, the bottom gravel being considered of too low grade. The small gravel areas near Camptonville are almost exhausted, but much gravel still remains at Depot Hill, in the northeast corner of the quadrangle. An area of shallow Neocene gravel has been worked at New York Flat, and in this the gold appears to be largely derived from the adjacent Forbestown quartz veins. At Smartsville and Sicard Flat extensive hydraulic mines have been located. At the former hydraulic washing was still being carried on some 10 years ago, the débris being stored in an old gravel pit. Drift mining is done on the same channel, the deposits having been opened from a point near Mooney Flat.

About 2 miles south of Wyandotte the Neocene shore gravels have been washed by the hydraulic process and are well exposed. They contain layers of yellow friable micaceous sandstone.

[1] House Ex. Doc. 267, 51st Cong., 2d sess., 1891.

[2] Op. cit., p. 206.

The Neocene river channel to the north of Bangor has been mined by means of drifting from shafts.

Extensive deposits of alluvial gravel derived from the hydraulic mines lie in Willow Creek near Camptonville and in Deer Creek below Nevada City; these may in the future be worked over again.

IONE FORMATION.

During the Miocene epoch, contemporaneously with the accumulation of the auriferous gravels on the slopes of the Sierra Nevada, there was deposited in the gulf then occupying the Great Valley a sedimentary series consisting of clays and sands, to which the name Ione formation has been given.

In this quadrangle there are very few exposures of this formation, most of it being either covered by the Pleistocene beds or removed by erosion before their deposition. Good outcrops of the clays and sands constituting this formation are found on Dry Slough 8 miles northeast of Wheatland, and also on the road to Spenceville 5 miles from Wheatland. At Dry Slough the beds are about 15 feet thick, dip gently southward, and are overlain unconformably by thin Pleistocene gravels. On the Spenceville road impressions of fossil leaves are found in a yellowish clay. West of the Brady ranch 20 feet of whitish clay and sandstone underlie the andesitic conglomerate. Along Honcut Creek the Ione formation appears to have been almost entirely eroded before the deposition of the Pleistocene clays and gravels.

AURIFEROUS GRAVELS.

The Neocene topography of this quadrangle differed materially from its topography of to-day, but the difference in the configuration is, on the whole, less marked than in other areas, because a large part of this district was never covered by volcanic flows, and consequently the older drainage is to some extent preserved. The principal feature of the Neocene topography consisted of the high and rugged diabase ranges of the foothills, rising to an elevation of over 1,500 feet above the rivers. To the east of this high foothill range, on the middle slopes of the range, gentler outlines prevailed, but the general character was still decidedly hilly and undulating. The principal river then draining the area corresponded closely to the present Yuba River. Bear River was represented only by a less important creek, for in the adjoining Colfax quadrangle the south fork of the Neocene Yuba River cut off the present upper drainage of the Bear. The Neocene channel at Bangor may be considered as representing, in part, the present Honcut Creek.

In tracing the Neocene drainage in detail many difficulties arise on account of the great extent to which the Neocene deposits have been removed by erosion. The main channel of the Neocene Yuba enters the quadrangle east of Paterson and, forming a curve convex to the south, is at Badger Hill crossed by the canyon of the present Middle Fork of the Yuba, which has here cut down to a depth of 1,000 feet below the old channel. From Badger Hill to North San Juan the main Neocene channel must have followed the present river canyon. From North San Juan to French Corral the course is unmistakably marked by a succession of gravel areas, now largely removed by hydraulic mining. Along this course the bedrock hills rise on both sides 500 to 600 feet above the Neocene channel, showing very clearly the character of the comparatively narrow and steep river valley. Through the diabase ridges of the foothills there is but one possible outlet for this channel, namely, at Smartsville, at the place where the present river breaks through these diabase hills. Between Smartsville and French Corral there is but one course which the old river could have followed, namely, the river canyon of to-day, and as a consequence nearly all traces of the deposition between these two points were removed as the canyon was deepened. At French Corral the depth of post-Neocene erosion is about 700 feet; at Smartsville it is not more than 200 or 300 feet.

This main stream received, near Badger Hill or North San Juan, a tributary from the vicinity of Camptonville, as indicated by Galena Hill, Weeds Hill, and Depot Hill (southeast of Oak Valley). This north fork of the Neocene Yuba River headed farther northeast, in the

Downieville quadrangle. Near French Corral Yuba River must have received another tributary, which headed south of Nevada City and the course of which is probably indicated by the Manzanita channel (at Nevada City), Round Mountain (4 miles north of Nevada City), and Montezuma Hill. Another tributary, heading in the vicinity of Grass Valley and Nevada City, is pretty clearly indicated by a few remaining areas; it probably joined the main river near Mooney Flat. A large section of the channel is preserved at Smartsville, the topography showing clearly the comparative narrowness of the old canyon cut through the greenstone ranges. Below Smartsville the course of the channel was approximately identical with the present river. Fragments of the channel are preserved at Sicard Flat and on the south side of Yuba River about 6 miles west of Smartsville.

The Neocene channel at Smartsville has a grade of 113 feet to the mile; the French Corral–North San Juan channel, 65 feet to the mile; the Camptonville channels, about 112 feet to the mile; the Badger Hill channel is almost level; the Manzanita and Cement Hill channels of Nevada City have a very slight fall. The grades of the old channels with westerly or southwesterly direction have been greatly increased since Neocene time by the tilting of the Sierra Nevada.

The auriferous gravels which accumulated in the Neocene river bottoms may be divided into two classes—those that antedate the Neocene volcanic activity in the Sierra Nevada and those that were contemporaneous with the rhyolitic and andesitic eruptions. The former consist of coarser and finer gravels of well-rounded pebbles of quartz and siliceous metamorphic rocks, with some sand; the color of the gravel banks in fresh exposures is usually white or yellowish. To this class belong the gravels of Camptonville and the large accumulation from a point east of Paterson down to French Corral. The thickness of these beds varies, but is in places considerable, averaging 150 feet between French Corral and North San Juan and reaching 400 feet east of Paterson. These accumulations are heavier along the old Yuba River than along any other Neocene streams of the range. One of the causes producing this accumulation was certainly the presence of a barrier near the mouth of the river, consisting of a high ridge of hard greenstone through which the stream must wear its way, thus, as it were, impounding the gravel in the upper course, which was characterized by wider valleys and more gently undulating outlines. The gravels on the tributaries of the main river had probably not accumulated to any considerable depth at the beginning of the volcanic period.

The well-worn gravel of the old river channel to the north of Bangor is undoubtedly of Neocene age. The gravel of this channel merges into heavy shore gravels, which are thought to be largely of Neocene age and which grade into Pleistocene shore gravels; the line separating the shore gravels of the two periods must be taken as an approximate one.

Gravels which occur interstratified with rhyolitic or andesitic material are found at several points. The upper part, at least, of the gravel at Smartsville and Sicard Flat is of this character and contains many pebbles of andesite. The total depth of gravel at Smartsville is not less than 200 feet. Most of the gravels of Nevada City also belong to the earlier part of the volcanic period, as rhyolitic tuffs are found low down in the series exposed there. Several of the smaller gravel areas exposed between Mooney Flat and Rough and Ready carry andesitic and metamorphic pebbles mixed and belong to the volcanic period.

A period of erosion intervened between the rhyolitic and andesitic eruption, but it was not of long duration, and the time did not suffice to establish well-defined and independent channels of the volcanic period.

The high, isolated area of well-washed gravel 3 miles north-northwest of Montezuma Hill is noteworthy; it is so much higher than the adjacent gravel channel of North San Juan that it must be assumed to belong to an earlier period; very likely it is of Cretaceous age.

RHYOLITE.

The heavy volcanic flows which usually overlie the auriferous gravels are not extensively represented in this tract. The earliest eruptions of the Neocene volcanoes in the portion of the high Sierra east of this tract were of rhyolitic character and swept down as mud flows along

the valley of the old South Yuba in the Colfax quadrangle. In the Smartsville area they are eroded along the principal channel. The only rhyolitic beds of importance are found immediately north of Nevada City, at Round Mountain (4 miles north of Nevada City), and at Montezuma Hill. These mud flows poured into the Nevada City drainage basin from one or two low gaps separating it from the valley of the old South Yuba to the east, and reach, in the vicinity of Sugar Loaf Mountain, north of Nevada City, a total thickness between 200 and 300 feet. They consist of white or light-colored sands, locally consolidated as soft sandstone, and sandy clays interstratified with gravels in such a manner that it is extremely difficult to draw the line between the two formations. The gravels, however, predominate in the lower part of the series. Some of these white sandstones or clays consist entirely of rhyolitic fragments, but others are mixed with detrital material from the surrounding formations.

ANDESITE.

Where no rhyolite is present the andesitic beds directly overlie the auriferous gravels. The lower part of the andesitic series usually consists of heavy volcanic gravels and tuffs which contain no gold, or only traces of it. The upper part is formed by a compact gray or brown andesitic breccia, with large angular fragments of andesite, cemented by finer, ground-up andesitic detritus. The breccia came down as successive mud flows from the volcanic vents located near the summit. The maximum thickness of the andesitic beds is 300 feet. The present areas represent but a small portion of the volcanic sheet once covering the country. At some places, as at French Corral, there is no andesite at present, but small patches remaining in the vicinity, such as the small area 3 miles north-northwest of French Corral, show that the depth of volcanic material must have been very considerable. It is evident that the andesitic flows once covered a large part of the northeastern section of the Smartsville quadrangle, but the Oregon Hills and the high diabase ridges of the foothills were not buried. At Smartsville the volcanic capping consists of alternating strata of conglomerate or compact gravel and compact tuff; the thickness does not exceed 150 feet. Below Smartsville the andesitic masses spread out and form a large area skirting the foothills for some distance at an elevation of about 200 feet; they are here comparatively thin, being not over 50 feet thick, and consist of black volcanic gravel or conglomerate, capped by a thin layer of andesitic breccia. To the west the andesitic beds soon disappear under the Quaternary covering.

TERTIARY GRAVELS OF THE NEVADA CITY AND GRASS VALLEY DISTRICTS.

In 1894 a special examination was made of the Nevada City and Grass Valley districts, the results of which were published in two reports.[1] The maps accompanying these reports are in three sheets—the Nevada City, Banner Hill, and Grass Valley special maps.

AURIFEROUS GRAVELS.

The auriferous gravels proper, resting directly on the surface of the "Bedrock series" along the depressions of the Neocene rivers and creeks, consist, in the larger channels, of well-rounded pebbles of quartz and harder rocks of the "Bedrock series," between which lies more or less sandy material. Although the pebbles are mainly of quartz, those of other material are also plentiful. The pebbles range from a fraction of an inch upward to 6 or 8 inches in diameter, but the average size is far short of the maximum. On the bedrock larger, partly rounded fragments occur here and there. Well-rounded bowlders several feet in diameter are found in the bottoms of some of the channels with granitic bedrock. In many of the tributary channels, such as the Harmony and the channel at the northwest end of Cement Hill, the gravel on the bedrock is partly angular and imperfectly washed. In the Harmony channel bodies and streaks of bluish clay alternate with streaks of gravel near the bedrock. (See fig. 9, p. 131.) In the upper part of the gravel the pebbles are in general extremely well rounded and polished and consist largely of black siliceous rocks. The deepest gravel has generally a dark-gray

[1] Lindgren, Waldemar, Gold-quartz veins of the Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 1-262; Nevada City special folio (No. 29), Geol. Atlas U. S., U. S. Geol. Survey, 1896.

or bluish color and contains much secondary pyrite or marcasite, locally auriferous; streaks of reddish gravel also occur in the deeper parts of the mass. Nearer the surface the gravel is generally reddish. Fluviatile stratification is of extremely common occurrence. Very little gravel occurs in the Banner Hill area, though the lower parts of now largely eroded Neocene stream channels doubtless contained much of it. The Grass Valley area and the southern part of the Nevada City area also contain little gravel. The largest accumulations are found north of Nevada City, in the deepest parts of the ancient stream system, where they reach a maximum thickness of 175 feet at the Manzanita hydraulic cut (Pl. II, *A*, p. 20). The banks of Cement Hill show 60 feet of well-washed gravel, with excellent fluviatile structure.

RHYOLITIC TUFFS.

Above the auriferous gravels lie, in the deeper parts of the depressions, a series of light-colored or white clayey or sandy rocks, more or less perfectly consolidated, commonly described as pipe clay and sand. These are largely rhyolitic tuffs, more or less pure. Certain of the beds consist almost exclusively of minute fragments of glass; others are so admixed with mainly granitic detritus as nearly to mask their tuffaceous character. The fragments both of glass and of granitic minerals are generally very sharp and angular. Bodies of gravel are also included in the tuffaceous series, and, on the whole, it is impossible to draw a distinct line between the auriferous gravels and the rhyolitic tuffs. On the southern face of Cement Hill the line between the two formations is fairly sharp, separating 60 feet of gravel from over 200 feet of rhyolitic tuff. A little rhyolitic material is found in the sands of the main channels down to a distance of 40 feet, or even less, from the bedrock. The rhyolitic tuff is practically confined to the northern part of the Banner Hill and Nevada City tracts.

The purest tuff has very nearly the composition of a rhyolite. Grains and flakes of a brownish, translucent mineral, with faint double refraction, are abundantly developed, especially in the rocks poor in alkalies. This is undoubtedly the kaolin mineral recognized by H. W. Turner in his Ione sandstone.[1]

At the Cement Hill diggings, in the northwest corner of the Nevada City area, sandstones and gravel occur cemented by an almost pure, yellowish opal.

ANDESITIC TUFFS.

The high, gently sloping ridges of these districts are covered by andesitic flows, generally tuffs and tuffaceous breccias. These flows consist mainly of a detrital mass well cemented and made up of andesitic grains. Abundant angular or roughly rounded fragments of andesite of all sizes up to a foot or more in diameter are inclosed in this finer-grained mass. This andesite is of a gray to brown or reddish color, rarely greenish, and is in general distinctly porphyritic, with small crystals of white feldspar and black augite or hornblende. As a rule it has a rough, trachytic appearance. Mica is rarely found. Pyroxene (both augite and hypersthene) is almost invariably present. Black basaltic hornblende commonly occurs with the pyroxene, usually in larger crystals. The groundmass is partly glassy, or of a very fine-grained, holocrystalline structure. The thickness of the volcanic flows ranges from 400 feet in the Banner Hill district to about 200 feet in the Nevada City district. The easily distintegrating cement renders the exposures unsatisfactory, and a deep reddish soil usually covers the tops of the ridges. This disintegration and the tendency of the decomposed material and residual andesitic bowlders to slide downhill makes the contacts with the underlying formations in many places obscure and difficult to trace. Good exposures are found in the vicinity of the Harmony gravel mines. The best exposure, though practically inaccessible, is in the bluff of the Manzanita hydraulic pit, north of Nevada City, where resisting unconformably on the sloping surface of the white clays and sands there are at least four distinct flows of andesitic tuff, each 20 to 30 feet thick, separated by irregular, worn surfaces. The amount of angular andesitic bowlders is not constant, and some flows consist entirely of the fine, detrital cementing tuff. Of such character are the tuffs overlying the clays and gravels exposed in the hydraulic pit just north of Grass Valley.

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[1] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 464.

THE TERTIARY BEDROCK SURFACE.

Excellent opportunities are offered in this district to study the old Tertiary surface. The areas covered by the gravel deposits are numerous. The elevations along the contact lines and the data available from the underground exploration of the auriferous channels afford sufficient materials from which to construct a contour map of the Tertiary surface.[1] The general features of the contour map show a surface of prominent relief, but much less cut and scored by deep creeks and ravines than the modern surface. Banner Hill, the Town Talk ridge, and Osborne Hill were then, as now, salient points of the topography. These eminences rose from several hundred to over a thousand feet above the deepest depressions. Banner Hill was, however, an unusually prominent point in this part of the comparatively gentle middle slopes of the Neocene Sierra, its hard siliceous breccias strongly resisting disintegration. North of Banner Hill a prominent high ridge of siliceous argillite divided the Nevada City basin from the main Yuba River, flowing from Scotts Flat northward toward Blue Tent and North Columbia.

West of Town Talk the drainage was clearly westward, down toward Rough and Ready. The northern part of the Grass Valley tract was drained by the Alta channel, heading northeast of Osborne Hill. There is no evidence that the channel continued eastward to Buena Vista slide, as suggested in a previous publication.[2] The channel at Buena Vista probably graded toward the east to the main Yuba River. Good proof of this is furnished by the fact that the rhyolitic tuff from the main Yuba channel also flooded the Buena Vista channel and the depression southwest of the Washington mine, but did not overflow into the basin of the Alta channel.

In the Nevada City district the main depression was in the vicinity of Nevada City, for there the accumulations of gravel, sand, and clay are deepest and the elevations of the bedrock lowest. Up toward the highlands of Town Talk and Banner Hill the depth of this material grows less, and at a certain elevation the andesitic tuff rests directly on the bedrock. In the lower part of the basin the curious feature is presented of an almost continuous channel 4 miles long and practically level.

From Peck's diggings, at the head of Native American Ravine, in the northwest corner of the Nevada City tract, where the elevation of the lowest bedrock is 2,650 or 2,660 feet, there is without doubt a continuous channel to the Empire shaft, where the lowest bedrock elevation is 2,660 feet. Again, there is no reasonable doubt that the channel is continuous to the great hydraulic pits northwest of Nevada City, and here again the bedrock elevation is 2,650 feet or less, sinking to 2,625 feet in the vicinity of the old Merrifield mine. From this point the lowest channel continues eastward over the exposed bedrock of the hydraulic ground, at elevations ranging from 2,630 to 2,640 feet. At the south end of the Manzanita channel the elevation is 2,645 feet. From the Manzanita pit the rich gravel on the bedrock, a few feet thick, has been drifted on up to the Odin mine, where the elevation of the lowest bedrock is 2,655 feet. From the Odin incline the channel has been extensively prospected in the belief that it connects with the Harmony channel under the lava hill. The channel is here wider and the gravel of lower grade than farther south. At the Howe cut, where the channel emerges from under the ridge, the lowest bedrock has an elevation of 2,650 feet, though at the inner part of the cut a harder, granitic bedrock ledge rises to an elevation of 2,670 feet. Such local inequalities are observed in many of the old channels. There is thus no decided evidence to be derived from the grades as to the direction of the old channel.

Other facts show, however, that the Cement Hill channel, in the first place, must have flowed from the northwest to the southeast. First among them is the evidence from the gravel. At Peck's diggings there is only a few feet of imperfectly washed quartz gravel overlain by the clays and sandstones of the rhyolitic series, which here attain a depth of only 70 feet. At the diggings northwest of Nevada City the gravel is 60 feet deep, extremely well washed, and covered by 150 to 200 feet of light-colored rhyolitic beds. This alone shows plainly enough that the direction of the channel was southeasterly. Regarding the Manzanita channel, it has generally been supposed that it came down from the north and that, bending about near Nevada

[1] Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, Pl. II.
[2] Lindgren, Waldemar, Two Neocene rivers of California: Bull. Geol. Soc. America, vol. 4, 1893, p. 269.

City, its now eroded lower course followed the present valley of Deer Creek westward toward Rough and Ready. At the first glance this theory seems not only plausible but actually sustained by the grade of the channels, but there are very cogent arguments against it. In the first place, as in this vicinity the period of erosion between the rhyolitic beds and the andesite was insignificant, it should confidently be expected that some of the rhyolitic material would be found in the neighborhood of Randolph House and Rough and Ready, southwest of Nevada City, where fragments of channels are preserved. No such beds are, however, found there, the andesite tuff resting directly on the bedrock or the gravel. On the other hand, if we assume that the Manzanita channel did come from the north, we are confronted with the fact that the outlet of the Harmony channel at the Laney tunnel is somewhat lower than the bedrock at the Howe cut, so that, on this supposition—the outlet being to the east of the Howe cut—in no way could any connection then have existed between these two channels. That the Harmony channel is continued toward the northwest to join the old Yuba River is clearly shown by the lower deposits at Round Mountain and the still lower fragment of channel preserved at Montezuma Hill. There would thus be no room left for the headwaters of so large a channel as the Manzanita, on the supposition that it came from the north. Furthermore, the Manzanita channel was extremely rich in coarse gold. To the north of it are no quartz veins worth mentioning, while immediately to the south of it are the rich vein systems of Nevada City. On the west, toward the Providence mine, begin a series of much harder rocks, which are resistant to weathering and would easily form a barrier, just as the slate and diabase of Banner Hill, Federal Loan, and Town Talk still form barriers to the east and south.

The Manzanita channel then formed the central drainage way of a flat depression in the easily eroded granodiorite, bordered on the east, south, and west by an amphitheater of rising hills. This drainage line is indeed the most natural one to be expected in a vicinity where the tendency to transverse drainage is not so strongly developed as on the tilted plain of the modern Sierra Nevada. It has been shown in a former paper [1] that the grades of the Neocene river courses clearly indicate that such a tilting has taken place along an axis parallel to the crest of the Sierra and that the amount of it, though not exactly regular over the whole slope, was 60 or 70 feet to the mile as a maximum. On applying this principle to the Neocene drainage system of Nevada City the difficulties are overcome and the drainage becomes a very natural one.

The Cement Hill channel, with a direction from northwest to southeast, had, then, before the tilting, a grade of 60 or 70 feet to the mile. The partly eroded channel between the west end of the big hydraulic pits and the Manzanita pit, which now has a slight westward grade of 20 feet to the mile, had before the tilting an eastward grade of about 50 feet to the mile. The channel between the Manzanita and the Howe cut, now practically level (except for the hard projecting ledge at the cut), which runs nearly due north, had before the tilting a slight northward grade of about 20 feet to the mile.

From the Howe cut (elevation 2,650 feet) to the lowest bedrock at Round Mountain,[2] 2½ miles due north, or 1 mile east of the line of tilting (elevation 2,625 feet), the grade, which before the tilting was 30 feet to the mile, is now 10 feet to the mile. From Round Mountain to the lowest bedrock at Montezuma Hill (elevation 2,356 feet, according to Pettee in Whitney's "Auriferous gravels"), a distance of 2¾ miles in a direction nearly due west, there is now a grade of 100 feet to the mile, but before the tilting it would have been 30 feet to the mile. From Montezuma Hill down to French Corral, along Shady Creek and the present Yuba River, the only way which the Manzanita channel could have followed, the distance is 6 miles and the present grade 100 feet to the mile.

The Harmony channel must have joined the Manzanita channel a mile or two north of the Howe cut. The Harmony channel, coming down in a westerly direction, has now a very steep grade of about 150 feet to the mile from the East Harmony mine to the Laney tunnel. Before the tilting it had a grade of about 80 feet per mile. East of the East Harmony mine the grade

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[1] Lindgren, Waldemar, Bull. Geol. Soc. America, vol. 4, 1893, p. 296.

[2] See Smartsville folio (No. 18), Geol. Atlas U. S., U. S. Geol. Survey, 1895.

increases rapidly as the high ridge of siliceous argillite is approached. It has been held by many that the Harmony channel continues for an indefinite distance up the ridge. This is impossible, as only a few miles eastward the deep Yuba channel, from Scotts Flat to Blue Tent, crosses the ridge. The Harmony channel is well up toward the headwaters and under Harmony Ridge divides into several branches. The subangular character of its gravel and the steep grades prove that the divide is not far distant. Its richness is due not to its being a main and important channel but to its crossing a system of rich quartz veins. It is barely possible that a deep gorge cuts through the ridge of siliceous rock and extends as far east as the Fountain Head mine, but this must be characterized as highly improbable. The area in the vicinity of the Fountain Head mine probably drained eastward toward the main Yuba River. There is, of course, no reason why auriferous channels should not be found on the east as well as on the west side of the divide. There is also a difference in elevation between the surfaces of the rhyolitic flows of 200 to 300 feet between the vicinity of Cold Spring and Fountain Head. So great a difference would scarcely exist if there had been a way of communication between the two localities.

Considering the subsequent tilting, the Tertiary bedrock surface must originally have had a less sharp westward slope than at present. Banner Hill, instead of rising 1,250 feet above the Manzanita channel, as now, was only 1,050 feet above the channel.

DEPOSITION OF THE AURIFEROUS GRAVELS.

The surface on which the Tertiary deposits rested having thus been examined, it remains to outline briefly the events which caused its burial under Neocene sedimentary and igneous deposits. At a period immediately preceding the volcanic eruptions of rhyolite and andesite the accumulations of gravel were not deep in any part of this area located well up on the ridges dividing the main drainage lines. Along these main rivers, and principally along the great longitudinal valley of the Yuba from You Bet up to North Columbia, masses of gravel several hundred feet in depth had accumulated. One of the principal causes (though not the only one) of this exceptionally heavy gravel mass is to be found in the fact that Yuba River, flowing on the middle slopes in a broad and open valley, had to turn and force its way through the foothill range of Jurassic lavas in a relatively deep and narrow canyon, almost as deep as that of to-day and well shown by the present relations at Smartsville. This foothill range acted as a barrier, restraining the gravel masses in the open valleys of the middle slopes. In the Nevada City area the prevolcanic gravels reached the greatest depths along the Manzanita channel, and it is doubtful whether they have at any place exceeded a thickness of 40 feet. Rhyolitic fragments are found at that elevation above the bedrock, and even lower. It is doubtful whether the gravels, 60 feet thick, of the hydraulic pits northwest of Nevada City are antevolcanic; the gravel is different from that generally found in the deepest parts of the Neocene channels and has more the appearance of the extremely well washed "black gravel" which occurs at the higher elevation and which belongs in the rhyolitic period. Outside of the main drainage channel there was only a few feet of gravel on the bedrock along the streams, and in by far the greatest number of exposures the andesite or rhyolite rests directly on the bedrock. There is no reason to believe that the antevolcanic gravel in this vicinity antedates the Neocene period.

THE VOLCANIC FLOWS.

Such were the conditions when eruptions of enormous masses of rhyolitic tuffs began on the headwaters of the Tertiary Yuba River. Their general character has been referred to above. It is probable that they were erupted as mud flows, emerging from the crater mingled with much water, and that there was not only one but a long series of flows, in the intervals between which the older flows were to some extent worked over by the running water and interstratified with clay, sand, and gravels of local origin. These rhyolitic flows, 200 to 300 feet thick, are well exposed at Alta, on the Central Pacific Railroad, and at Chalk Bluff, near You Bet, both in the

Colfax quadrangle. At Chalk Bluff an extensive Neocene flora was collected by C. D. Voy and examined by Leo Lesquereux.[1] The rhyolitic flows of Nevada City are the exact stratigraphic equivalent of the rhyolite tuff of Chalk Bluff, and there can thus be no doubt about their age. Leaves similar to those of Chalk Bluff occur at many places in the vicinity of the Manzanita channel, and with some trouble it may be possible to obtain a good collection.

The tuffs are well exposed at Quaker Hill and Scotts Flat, farther down the Neocene river, and again at the north side of the Washington ridge at Blue Tent, where they are several hundred feet thick, the top stratum attaining an elevation of 3,000 feet. Near the place where the upper North Bloomfield road crosses Rock Creek there was a low gap in the ridge between the main Yuba and the Nevada City basin; through this gap the rhyolitic tuffs poured into the granitic basin. The first flows found their way down into the Harmony and lower Manzanita channels, causing a damming of the latter, which, of course, produced an accumulation of sand and gravels in the upper part of the channel about Nevada City, and to this damming it is believed the heavy gravels of the Manzanita cut and Cement Hill are due. Subsequent flows found their way down to Round Mountain and Montezuma Hill, obstructing the channels to still greater extent. At last the whole of the lower part of the Nevada City basin became filled. The elevation of the top layers now ranges from 3,100 feet on the east side of the basin to 2,740 feet at the northwest corner of the Nevada City tract, a distance of 5 miles from east to west. It will be noticed that on the supposition of a tilting of 70 feet to the mile the surface would once, over this distance, have been approximately level, and about at the same elevation as the top stratum of the rhyolitic tuff at Blue Tent. The rhyolitic tuffs did not reach the southern and highest part of the Nevada City basin, nor did they overflow into the Town Talk or Grass Valley channel. To the east of the Neocene divide, rising along the eastern margin of the Grass Valley tract, the rhyolitic flows again appear, having reached that locality from the vicinity of You Bet. The divide was, however, just high enough to prevent their overflowing into the Alta channel.

As may be seen by tracing the contacts of andesite and rhyolite, the surface was not even but was subjected to some eroding action in the interval between the two eruptions; the erosion, however, was not extensive enough to produce any marked change. In fact, intervolcanic channels, cutting far down into the rhyolite and even into the underlying bedrock, such as are so characteristic of the vicinity of Forest Hill, Placerville, and Mokelumne Hill, in the drainage of the Neocene American and Mokelumne rivers, are practically absent on the main Yuba, although they appear on the headwaters of the North Fork of the Yuba, near Forest City. This is evidently caused by a differing time interval between the two eruptions; in this vicinity the first andesitic flow from the Lola and Castle Peak volcanoes followed closely after the last eruption of rhyolitic tuff.

During the later part of the rhyolitic period many divides were flooded and the drainage was partly changed. The great Neocene orogenic movement of the Sierra probably took place between the rhyolitic and the andesitic eruptions, as is indicated by the intensely eroding character of the "cement" channels, or intervolcanic channels. A tilting took place, elevating the eastern part of the range most strongly and the western part but little. Flows of andesitic tuffs, emerging from the craters as a mud, poured down the flanks of the Sierra in rapid succession, obliterating the old drainage system and flooding many of the divides, so that Banner Hill and Osborne Hill alone emerged from the desolate lava plateau in this vicinity. On this inclined lava plain the rivers had to select new courses, in general differing considerably from the old ones. The present drainage system was developed, characterized more than the Neocene by a transverse direction of the rivers.

[1] The exact locality seems a matter of some doubt. It is not now accessible, having been covered by hydraulic débris. Whitney states that the matrix is a rhyolite tuff, but in the few specimens I examined, by the courtesy of Prof. A. C. Lawson, of Berkeley, the rhyolitic character is not clearly apparent under the microscope. At the locality I was told that the leaves were found in clay just below the white tuff and at the top of the extensive bench gravels of You Bet, several hundred feet above the bottom of the deepest channel.

MINING OPERATIONS IN THE GRAVELS OF NEVADA CITY AND GRASS VALLEY.

The Neocene auriferous gravels, of which some are exposed and others are buried under several hundred feet of unproductive clay, sand, and volcanic material, lie from 200 to 500 feet above the bed of Deer Creek. Wherever exposed without heavy covering they have been washed by the hydraulic process, by which the whole mass of the gravel is removed. The richest gravels in the bottom of the old stream are removed by drifting along the bedrock and subsequently washing the mined gravel. Hydraulic mines have not been operated in the district for the last 15 years on account of the débris litigation. The only ground suitable for extensive mining by the hydraulic process is found near Nevada City.

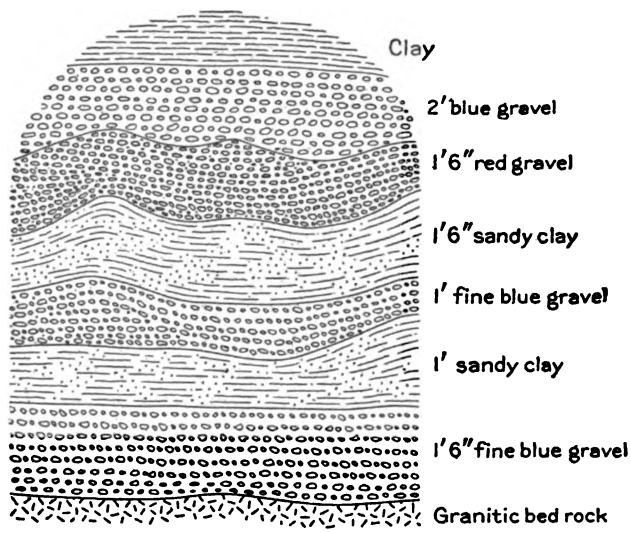


FIGURE 9.—Section of breast of workings, West Harmony drift mine, Nevada City, showing character of deposits in a small tributary stream.

Within the area of the Nevada City and Banner Hill special maps the mining developments are as described below. A large opening has been made to mine the channel south of Deer Creek, a short distance southwest of the Lecompton mine. As the gravel is very thin and a bank of 100 feet of andesitic tuff is already exposed, not much more can be accomplished by hydraulic methods. Drifts have been run for a short distance, but no work is being done now. The same statement applies to the hydraulic cut south of the Murchie mine, where a minor channel runs north and south. For some distance from this point along the rim, hydraulic work could be prosecuted. To the east the bedrock rises steeply. Thence southward to the reservoir smaller hydraulic cuts have been made at intervals along the lava contact, either on smaller channels or, more commonly, on the decomposed croppings of quartz veins extending under the lava. Especially extensive are the old pits in the vicinity of the Mayflower mine, where some ground is yet left for hydraulic operations. Small tunnels have been run in under the lava at several places.

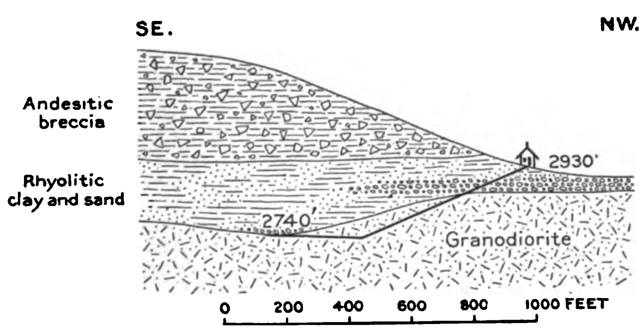


FIGURE 10.—Vertical section along Yosemite incline, Nevada City.

The drifting operations under Harmony Ridge are extensive. The Harmony channel with its branches has been opened and worked profitably by the Cold Spring incline and lately by the East and West Harmony inclines (fig. 9). A northern branch has been mined from the Stokes shaft and other places in the vicinity of Munroe's vineyard. South of this attempts to reach the same channel have been made at the Yosemite incline (fig. 10) and at the edge of the Banner Hill district. The Allison tunnel and incline were driven in search of the continuation of the Harmony channel in 1894. In the adjoining district it has been mined almost continuously from the Coleman shaft and the Nevins and Laney tunnels to its outlet. The pay gravel in the Harmony channel is from 150 to 200 feet wide and only from 2 to 4 feet deep. It is in many places subangular and contains many quartz bowlders. Gold-bearing quartz veins are exposed here and there in the bed. As the gravel is firmly cemented, it must be crushed in stamp mills in order to extract all of the gold.

The Manzanita channel has been worked extensively by the hydraulic method from its south end, and also to some extent at the north end, at the Howe cut. Between these points it has also been drifted almost continuously by the Manzanita, Nebraska, Live Oak, Odin, and other companies. Near the Nebraska incline the channel was narrow and especially rich, while to the north the gravel spreads out considerably and is more spotted in character. The channel is estimated to have produced over $3,000,000. The most extensive hydraulic mines are southwest of Sugar Loaf Mountain, where an area of at least 100 acres of bedrock has been exposed. The different portions of this ground, from east to west, are referred to as Buckeye Hill, Oregon Hill, Coyote Hill, Lost Hill, Wet Hill, and American Hill. Over this ground the gravel probably averaged 60 feet in thickness. The last work done before the débris litigation was in the extreme northwest corner and is referred to as the Hirschmann cut; from this it is said $100,000 has been taken. The whole mass hydraulicked contained, roughly, 10,000,000 cubic yards and has probably yielded several million dollars. The hydraulic operations could be continued for some distance northward, to the point where the overlying clays and tuffs become too heavy for profitable handling.

To the north the bedrock rises slowly, but in a northwesterly direction it continues low and the ground has been opened by the Knickerbocker and Grover tunnels, in which good pay is found in spots. Still deeper is the Phoenix tunnel, on which the last work was done about 1880. It is about 1,200 feet long, in hard granodiorite, and struck gravel in an upraise of 15 or 20 feet near the end. The gravel did not show good pay. From this point northwestward there are no developments till Ragon's claim and the old Empire shaft are reached. The shaft is 146 feet deep, and some rich gravel was extracted from it long ago. The channel has here the character of a narrow ravine. Some good pay has been found also higher up on the rim in Ragon's incline. The same channel is exposed also in the hydraulic cut on the north side of the ridge, in the extreme northwest corner of the Nevada City special quadrangle. Some drifting has also been done at this place, and the pay streak is said to have been 50 feet wide. At the Stevens & Trevasco mine a little hydraulic work has been done in the black gravel, and several tunnels have been run. The principal one is 420 feet long, with the bottom in bedrock at the face. On the northeast side of Cement Hill, near Dean, several long tunnels have been driven which, at a certain distance in, lose the bedrock and run into black gravel. Dean's new tunnel is 600 feet long at an elevation of about 2,700 feet and still entirely in bedrock. Black gravel has been struck in a 20-foot upraise.

Under the andesite ridge west of Town Talk there is a channel the bottom of which has not thus far been exposed. It seems to head near Town Talk, where the presence of a small channel was indicated in the railroad tunnel. The tunnel 1,000 feet west of Town Talk was made in 1880 and proved too high. Several tunnels have been run in along the rim on the north side of the ridge. The Carl tunnel was run 1,000 feet in bedrock and struck only clay and sand in an upraise. The Hughes tunnel is 500 feet long, in bedrock. The Schroeder tunnel is located at the outlet of the channel, in a small hydraulic cut, and drifting was going on there on a small scale in 1894. The elevation there is about 2,516 feet.

In the Grass Valley district the Alta channel has been drifted for about 3,000 feet from several shafts. The width of the channel was from 50 to 150 feet, but beyond the Hope shaft it appeared to widen, making the extraction less profitable. The total production is estimated to be $1,000,000.

Along the northern edge of the andesite area east of the Empire mine smaller hydraulic cuts have been made and 700 feet of the channel drifted. A small channel southeast of Heuston Hill was mined by drifting for about 400 feet in 1894.

CHAPTER 12. THE COLFAX QUADRANGLE

GENERAL GEOLOGY.

The "Bedrock series" in the Colfax quadrangle is represented chiefly by the Calaveras formation (Carboniferous) in its several subdivisions.[1] A strip of the Mariposa formation (Jurassic) lies along the southern part of the western margin, and a strip of the Sailor Canyon formation (mainly Triassic) along the east side. Intrusive in these altered sediments are amphibolites of many kinds along the west side and a large central dike of peridotites, serpentines, and gabbros, which traverses the whole quadrangle from north to south. A part of the granodiorite batholith of the high Sierra enters the quadrangle at the eastern margin, and along the west side lie several smaller intrusive masses of granodiorite and diorite. The list of important intrusive igneous masses closes with the body of soda granite that reaches up into the Downieville quadrangle from a point near Emigrant Gap, where only a narrow strip of contact-metamorphic slate separates it from the main granitic mass of the Sierra.

GOLD-BEARING AREAS AND PRODUCTION

The largest and richest masses of Tertiary gravel known in the Sierra Nevada are found in this quadrangle and derived their contents from a great number of gold-quartz veins. Few of these veins are continuous for a great distance, and the bulk of the gold was evidently derived from small veinlets and seams. Almost the whole area is gold bearing to a greater or less extent. The most barren parts are in the granitic rocks northwest of Cisco and in the clay slates of the southeast corner. The western margin of the quadrangle is followed by an irregular belt of gold-quartz veins from the Alaska and Delhi on the north to the great complex of veins around the south end of the granodiorite of Nevada City and to the veins in the vicinity of Colfax.

From north to south in this quadrangle the great Serpentine belt is followed by an enormous number of auriferous veins, few of which are continuous enough to warrant extensive mining, but which seem to have enriched, in an extraordinary degree, the gravels of the streams which flowed over them. East of the Serpentine belt, chiefly in slates of the Calaveras formation, but partly also in the soda granite, lies another strongly auriferous zone marked by continuous and longer quartz veins. This extends from Johnsville, in Plumas County, by American Hill, Graniteville, Eagle Bird, Blue Canyon, and Humbug Bar, and leaves the quadrangle south of Michigan Bluff. This zone is second only to the Serpentine belt in its enriching power. Some of its veins are continuous for several miles. The rocks are comparatively barren from this zone to the eastern boundary of the quadrangle, except at two places, one at Meadow Lake in the granodiorite, the other at Duncan Peak in the slates. The veins in the Duncan Peak auriferous area have enriched the surrounding gravels, which, however, are not extensive.

It is impossible to obtain exact data regarding the total amount of gold produced in this quadrangle. That part of Nevada County which is contained in it has certainly produced $60,000,000. The part of Placer County which is contained in it has surely produced, at the very least, the same amount. To this must be added the production from Minnesota, Alleghany, and Forest, in Sierra County, which is large. It is thought that $150,000,000 is a very conservative estimate of the total. Of this amount probably not more than $10,000,000 has been contributed by the quartz mines. The yield of the Nevada City and Grass Valley districts, just outside the quadrangle, is estimated at $123,000,000; of this amount about $75,000,000 may have been derived from the quartz mines in those districts. These figures are only the rudest approximations, but they serve to convey an idea of the astounding richness of the region.

[1] See Colfax folio (No. 66), Geol. Atlas U. S., U. S. Geol. Survey, 1900.

In 1908 the placer production of this quadrangle was about $280,000, and, so far as drift and hydraulic mining are concerned, it remained the most important area in the Sierra Nevada. The part of Nevada County in this quadrangle contributed only about $50,000, while the Forest Hill divide yielded almost the whole of the remainder, or $220,000; of this, $180,000 was derived from drifting operations.

In 1909 the placer production was about $537,300, distributed as follows:

Placer gold produced in Colfax quadrangle, 1909.

Sierra County: Forest City and Alleghany	$5,500
Nevada County:	
North Bloomfield, Relief, etc	1,000
Washington	1,500
Dutch Flat and Lowell Hill	14,700
You Bet	358,600
Placer County:	
Dutch Flat	2,000
Gold Run	36,000
Iowa Hill	47,000
Last Chance	33,000
Forest Hill, Michigan Bluff, Bullion, and Damascus	37,000
Scattered	1,000
	537,300

The large production at You Bet resulted from finding in drifting operations an exceedingly rich pocket in a part of the main Tertiary channel.

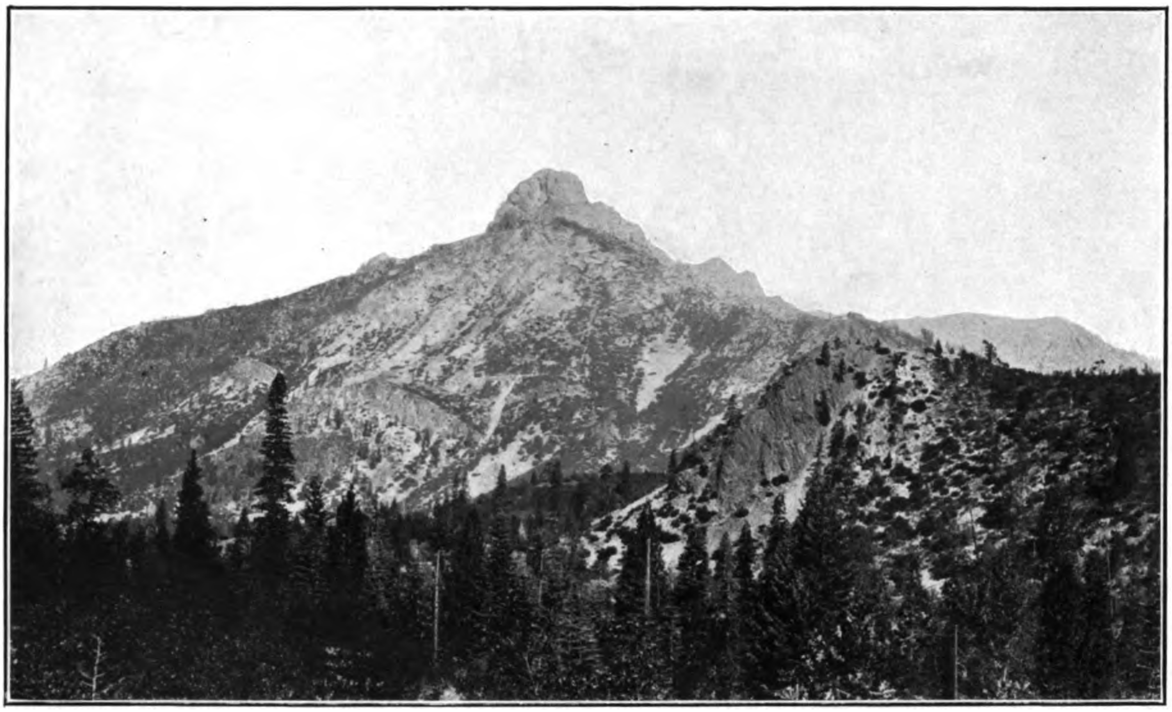
THE TERTIARY TOPOGRAPHY.

The Tertiary surface was in the main of an undulating, hilly character. The slopes lay at angles up to 10° and the rounded ridges rose to heights varying from a few hundred feet to 1,500 feet above the channels. In the eastern part of the quadrangle the conditions were somewhat different. Here the Tertiary topography was decidedly more abrupt. A number of prominent, flat-topped hills rose to a height of 2,000 feet above the watercourses. Among them are English Mountain, Signal Peak, Snow Mountain (in the Truckee quadrangle), Monumental Hill, and Duncan Peak (Pl. XVIII). There are practically no auriferous gravels in this upper region, embracing the eastern third of the quadrangle. Evidently the rivers of this region were able to transport easily all the material they received.

The outlines of the early Tertiary drainage system were as described below, most of the connections being established with considerable certainty. The drainage was partly transverse, flowing down the range like the present system of rivers, but in part it was also parallel to the present range, taking a course followed by none of the present rivers and clearly indicating a low range with longitudinal ridges. It is believed now that the whole of the Tertiary drainage in this quadrangle found an outlet in the important master stream which extended from North Columbia down to Smartsville, and to the waters of the gulf then occupying the Sacramento Valley. This principal stream broke across the longitudinal ridges of Jurassic eruptive rocks in a relatively deep and narrow valley.

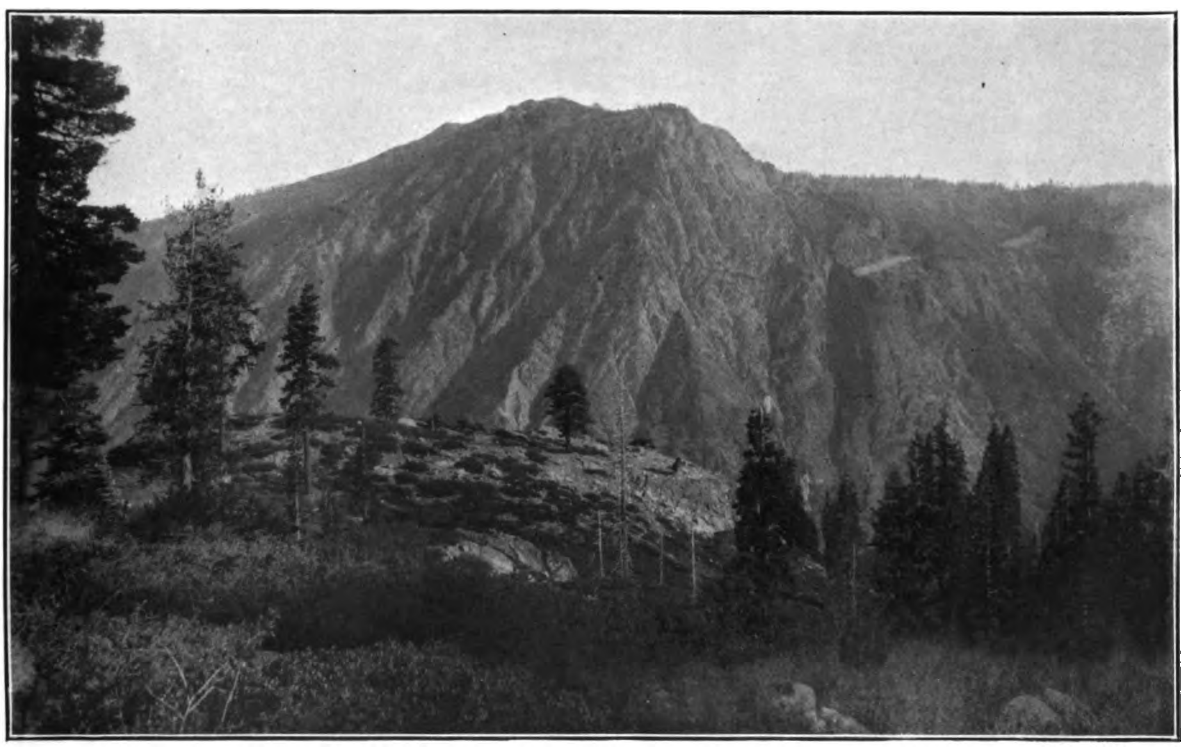
Near North Columbia the main trunk channel branched. The northerly channel continued eastward to North Bloomfield; there it turned north and then east to Moores Flat and Snow Point; then, crossing the present canyon of the Middle Fork of the Yuba it entered the Downieville quadrangle northeast of American Hill. A tributary to this channel followed in part the present Oregon Creek and joined it in the Smartsville quadrangle. Still another tributary ran by the way of the Derbec mine, Relief, Alpha, Omega, and Bear Valley.

The southerly branch of the trunk channel followed from North Columbia to Little York a broad longitudinal valley having a south-southeast direction, bordered on the west by a high ridge of diabase and slate. At Little York the channel bent sharply northeast to Dutch Flat, and tributary branches extended up to Alta, Lowell Hill, and Shady Run.



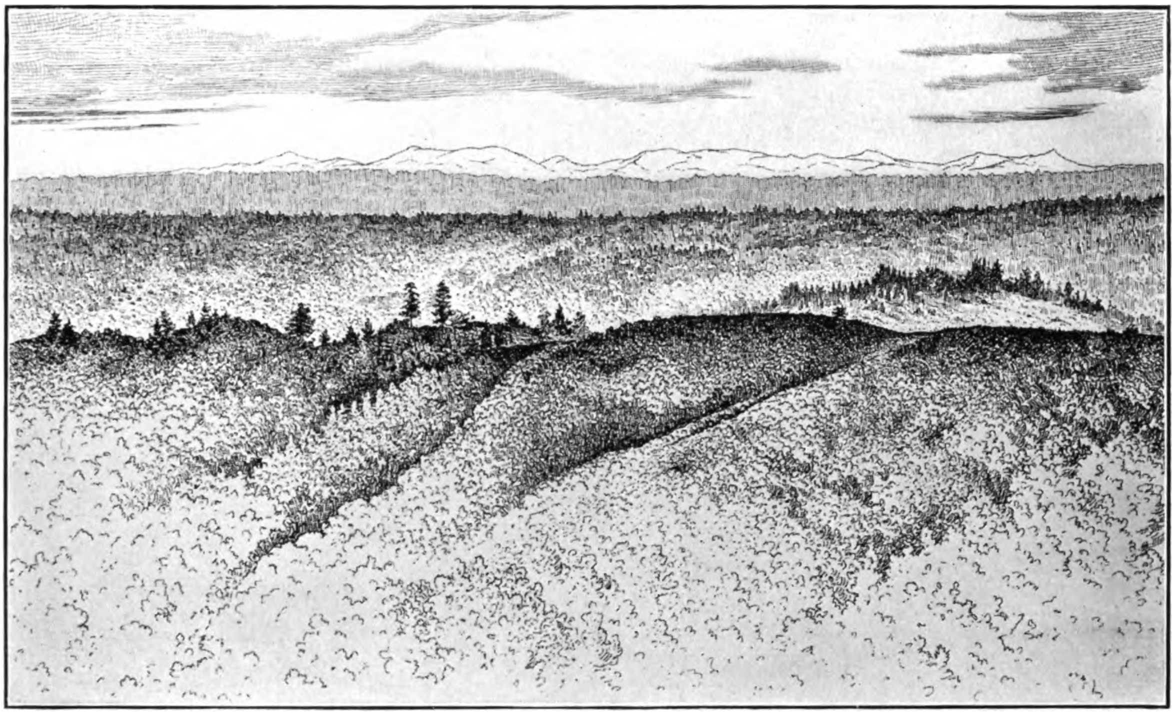
A. SIERRA BUTTES, IN THE DOWNIEVILLE QUADRANGLE, SIERRA COUNTY.

A part of the Cretaceous divide of the Sierra Nevada. Viewed from the south. Photograph by H. W. Turner. See page 38.



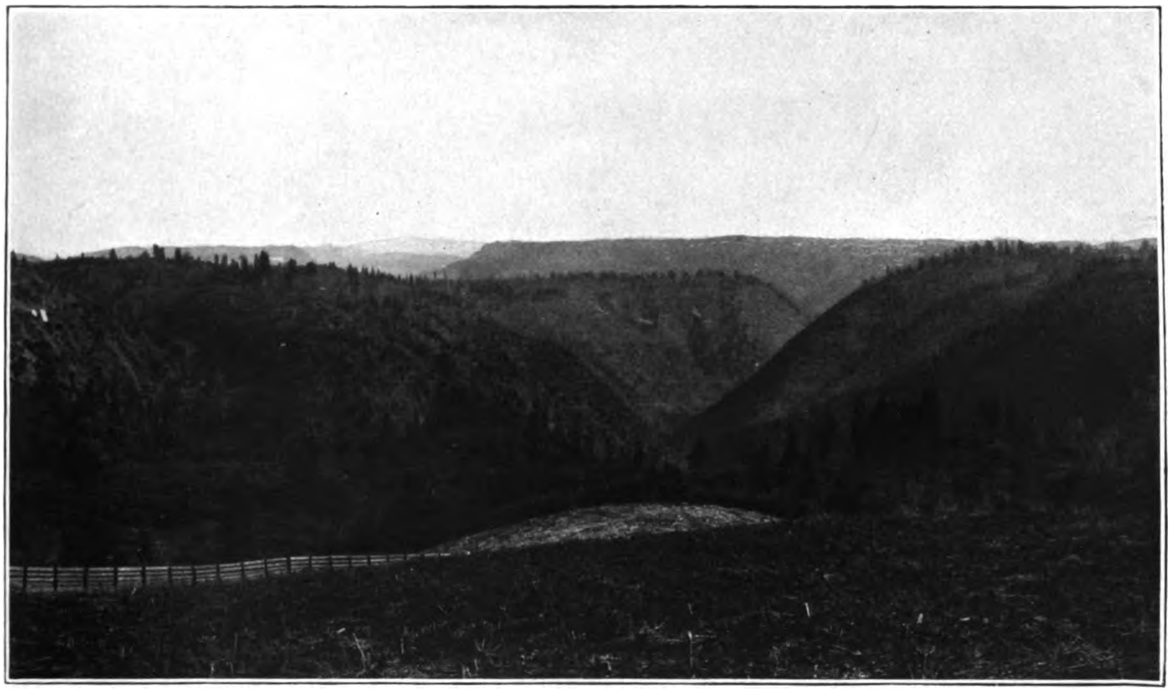
B. SNOW MOUNTAIN, IN THE TRUCKEE QUADRANGLE, PLACER COUNTY.

A part of the Cretaceous divide of the Sierra Nevada. Viewed from rhyolite bluff south of American River, about 300 feet above a Tertiary channel. Between the bluff and Snow Mountain the deep canyon of American River is eroded. Showing rough Tertiary topography near the old Cretaceous divide. Photograph by J. C. Hawver. See page 38.



A. VIEW LOOKING EAST FROM HILL 2 MILES NORTH OF AUBURN, PLACER COUNTY.

The view is across the two forks of American River to level lava ridges in the middle background and the high bedrock ridges of the Pyramid Peak Range in the far distance. From telephotograph by J. C. Hawver. See page 38.



B. VIEW LOOKING UP THE AMERICAN RIVER CANYON FROM A POINT NEAR COLFAX, PLACER COUNTY.

Giants Gap in the background. See page 38.

On the Forest Hill divide important channel systems have also been traced, but it was formerly believed that these found their outlet directly southwest toward the Great Valley. Later investigations, however, seem to indicate that this great channel system connected with that north of the basin of American River. In spite of some difficulties, explained more in detail below, it now seems probable that the longitudinal valley continued in the same general direction to Yankee Jim, and that the channel continued in the upstream direction by way of Dutch Flat, Indiana Hill, Iowa Hill, and Wisconsin Hill; further, that it turned eastward near Forest Hill and continued by way of Mayflower, Bath, and Michigan Bluff across the Middle Fork of American River to the Long Canyon divide. There is no doubt about its upper course from this point. After a short bend southward, extending into the Placerville quadrangle, it cut across the extreme southeast corner of the Colfax quadrangle, then continued in the Truckee quadrangle up by French Meadows and Soda Springs to its former headwaters south of Castle Peak. This important stream was joined by tributaries, the principal one coming down from Damascus to Michigan Bluff. This was again joined by lesser streams from Secret Canyon and Red Point and from Last Chance and Deadwood.

During the later part of the auriferous-gravel epoch the topographic conditions were materially different. The lower valleys were filled with gravel to a depth of several hundred feet, and the streams meandered over flood plains which locally attained a width of 3 miles. They became less able to carry the load of detritus, and deposits of clays and sands increased greatly. Low divides were covered, and many streams were diverted from their original channels. This phase became even more pronounced when, as a result of the rhyolitic eruptions in the high Sierra, vast masses of ash and fine volcanic detritus were piled up in the river channels. Overloading and deposition ceased only after the close of the rhyolitic eruptions or during the early stage of the andesitic eruptions when an uplift or westward tilting of the surface took place. The grade of the rivers being increased, cutting immediately followed, and in some regions, especially on the Forest Hill divide, proceeded to such an extent that new channels were excavated in the old river valleys without reference to the older courses, as narrow, steep-sided gorges cut into the soft sediments and even into the underlying hard "Bedrock series." A small amount of gravel accumulated in places along these intervolcanic channels, and many of such deposits are rich in gold reconcentrated from the older gravels. The streams of these channels were evidently able to transport the great quantity of material offered to them. Channels of this kind are few in the northern and central parts of the quadrangle. They have been noted, however, north of Forest and are especially prominent in the Ruby drift mine (in the Downieville quadrangle). One is also said to have been met with in drifting below the lava capping northeast of American Hill.

In the higher range the valleys were narrow and contained little detritus. The intervolcanic streams simply reexcavated or deepened these valleys without creating new channels. But on the Forest Hill divide and in the adjoining region the old deposits are repeatedly cut by intervolcanic channels, among which those representing two epochs may be recognized. Below Forest Hill these channels did not follow the old drainage lines but established new courses directly down the slope on the range by way of Peckham Hill (in the Placerville quadrangle). The interval between the rhyolites and the final andesitic eruptions must have been much longer here than farther north.

The present grades of the Neocene channels in this quadrangle are as steep as 150 feet to the mile, much steeper than any which could reasonably be expected in a region of comparatively gentle configuration. Almost the only exceptions are found among those principal watercourses which had a northwest or north-northwest direction. These have very slight grade. Most prominent among these is the Neocene South Fork of the Yuba, which from You Bet to North Columbia has an average grade of less than 17 feet to the mile. From these facts has been drawn the conclusion that the tilting movement of the range as a whole has added to the grades of all the rivers flowing in a general westerly direction but has not affected the rivers running parallel to the range. After the andesitic flow came the excavation of the deep canyons of the present day. Plate XIX, *B*, well represents the present appearance of the region and shows the level crests of the ridges capped with andesitic tuff abruptly trenched by the canyon of American River.

RHYOLITE.

The first eruptive flows of rhyolite and rhyolite tuffs did not cover large areas, but followed nearly all the main river courses. They were covered by later andesitic eruptions and are now exposed only where erosion has cut through the volcanic masses. The massive rhyolite is a light-gray or pink fine-grained compact rock, easily dressed, and showing in places small porphyritic crystals of quartz and sanidine. Its outcrops form many abrupt cliffs or bluffs. This rock occurs chiefly in the eastern portion of the quadrangle, typical exposures being those northwest of English Mountain, Sugarpine Flat, and Canada Hill. The vent from which the rhyolite of English Mountain poured out was located near Castle Peak or Mount Lola, at the summit of the range; the sources of the other two eruptions mentioned are not definitely located.

In the western part of the quadrangle the rhyolitic rocks consist chiefly of sandy or clayey tuffs, of brilliant white color. The rhyolite flows, being of moderate volume, closely followed the courses of the Neocene valleys and are therefore good indicators of the lowest depressions in the old surface. The massive flows, probably being viscous, did not extend far from their vents. The tuffs were evidently carried down by the streams as mud flows, deriving their contents from masses of volcanic ash accumulated near the vent. The auriferous gravels are covered at many places by extensive light-colored, fine-grained sandy or clayey beds, usually called pipe clay. The origin of many of these beds—for instance, at Moores Flat, Omega, North Bloomfield, and North Columbia—is uncertain. Probably all of them contain volcanic material, but they can hardly be considered as volcanic tuffs. Granitic sand is certainly an important constituent of many of them. They have been mapped with the auriferous gravels.

In the northwestern part of the quadrangle rhyolitic tuffs are scarce, although bowlders of rhyolite occur here and there in the breccias.

A once continuous flow of rhyolitic tuff can be traced along the course of the Tertiary South Fork of the Yuba, beginning east of Blue Canyon and extending down by Alta, You Bet, Quaker Hill, and Scotts Flat. Some of the first outcrops northeast of Towle consist of massive light-colored rhyolite, but below this nothing but rhyolitic tuffs of very sandy to clayey texture and brilliant white color can be observed. This tuff crops extensively in the vicinity of Alta, here attaining a thickness of over 300 feet. The flow once filled nearly the whole of the broad river valley and even overflowed the adjoining ridges in one or two places. At Iowa Hill, Independence Hill, and Monona Flat a thin stratum of rhyolitic tuff appears below the andesite, probably having found its way to this locality from the vicinity of Alta. From Dutch Flat to You Bet the rhyolite, as well as the overlying andesite, is eroded. It appears, however, at Chalk Bluff, so named from the brilliant white color of its exposures. Here from 100 to 200 feet of rhyolitic tuffs underlie the andesite. Similar exposures are found at Quaker Hill, Hunts Hill, and Buckeye Hill. In the vicinity of Quaker Hill the relations are especially interesting, as Deer Creek has cut through the whole Neocene river valley, affording an excellent section. At Blue Tent the gravels are overlain by about 200 feet of light-colored sands, but their rhyolitic character is not plainly indicated, and it is probable that the small amount of tuff remaining in the old river valley after the overflow toward Nevada City had taken place was greatly mixed with sands and clays of local origin.

One of the largest eruptions of rhyolite in the Sierra Nevada took place near Castle Peak, in the Truckee quadrangle. The molten rock followed the course of the Neocene American River along the present Middle Fork. It enters this quadrangle near the southeast corner, where it nearly fills the broad, flat Neocene valley and is excellently exposed along the slope to the north of Long Canyon. Some massive rhyolite is found at the eastern boundary, but below this nothing but white tuffs occur. The thickness of the rhyolite, which forms many bluff-like outcrops and contains intercalated bodies of gravel, is here from 400 to 600 feet. Excellent exposures are found near the Ralston mine. A fragment of the same channel is seen near Michigan Bluff, and at the base of Sugar Loaf near that town a little rhyolite is exposed. The same channel reappears at Bath and Mayflower, passing thence southward under the lava cover near Forest Hill. At Bath and Mayflower somewhat over 100 feet of rhyolitic tuff and intercalated gravels are exposed. At Forest Hill, along the bluff south of the town, the thickness exposed is from 40 to 130 feet.

ANDESITE.

After a considerable interval, during which the rhyolite lavas were much eroded, the volcanoes along the summit of the range began to pour out masses of the moderately basic lava known as andesite. During the rapidly succeeding eruptions andesitic material from these volcanoes was spread over the whole western slope of the Sierra Nevada. Practically the whole of the Colfax quadrangle was, after the close of the eruption, covered by an andesitic mass to depths ranging from a few hundred to over a thousand feet, the greater thickness being found in the northeastern and southeastern portions. Only a few points remained like islands above the surface of the vast lava masses. Among these are English Mountain, the Black Mountains, and Signal Peak; probably also Duncan Peak, as well as some ridges to the west of Duncan Canyon. The whole western part was submerged with the possible exception of Banner Hill. Pleistocene erosion has removed the larger part of the volcanic covering, but enough remains to cap the summit of nearly every important ridge to a depth of a few hundred feet. The andesitic rocks rest on rhyolite, gravel, or the older formations of the "Bedrock series." As a rule, the greatest depth is along the old channels, while the adjacent bedrock hills may have been only superficially covered. Throughout the area the andesitic rocks are of a fragmental character. They consist, as seen in good exposures, of strata ranging in thickness from a few feet upward. By far the most usual form is a tuff breccia consisting of andesite cemented by a dark-gray material consisting chiefly of finely ground-up andesite. The lower part of the beds consists at many places, especially in the western part of the quadrangle, of volcanic gravels, sands, clays, and fine-grained tuffs. Intercalated between these and always covering them are strata of the above-described tuff-breccia. In the lower part of the series may be found here and there small masses of a mixed gravel of quartz and metamorphic rocks. The tuff-breccia contains exceedingly little nonandesitic material. Scattered granite bowlders are included, as near American Hill and other places, the granite being identical with that occurring near the summit of the range. The andesite, as shown in the included bowlders, many of which reach 3 feet or more in diameter, is a rough and porous rock of dark-gray to dark-brown color. Porphyritic crystals of plagioclase feldspar are invariably present, as are also crystals of augite and hypersthene. Hornblende is less abundant, but appears in many rocks as small black, glistening needles. Biotite is of very rare occurrence. The groundmass in which these crystals are embedded has a structure varying from glassy to very fine grained microcrystalline. Although the structure of the tuff breccia is similar throughout the quadrangle, there appears to be a slight difference between that to the north and that to the south of the North Fork of American River. North of this stream the andesite bowlders in the breccia consist to a considerable extent of hornblende andesite, all, however, carrying also some pyroxene. The rocks have in general a grayish or brownish color. Besides these hornblende andesites there are a large quantity of ordinary pyroxene and sites. On the Forest Hill divide south of the North Fork the andesites appear darker in color and the pyroxenic rocks predominate.

The volcanoes which ejected these enormous masses were located along the crest line of the range. North of the watershed of American River the andesites originated from the volcanoes of Webber Lake, Mount Lola, and Castle Peak. South of that line they were poured out from the volcanic vents south of Tinker Knob (in the Truckee quadrangle), the lavas of which were of a predominatingly pyroxenic character. It is believed that these andesitic tuffs were largely carried down the slope, following the old river valleys as volcanic mud mixed with water. This mud consolidated or set like a hydraulic cement to a hard compact mass. Probably, however, dust showers from the volcanoes produced some of the material and other masses, especially near the base of the series, may have been worked over by the streams in the intervals between volcanic eruptions.

The only occurrence of massive andesite that flowed down as a molten mass is found 2 miles southwest of Cisco, at the head of Lake Valley, though flows similar to this are noted in the adjoining Truckee quadrangle. At this place a small bed 20 or 40 feet thick appears at the base of a tuff-breccia. It is an olivine-pyroxene andesite with large, clear feldspar crystals

and dense black groundmass, similar to the rock from Table Mountain, Tuolumne County, but it does not contain as much potash as that rock.

The surface of the lava flows, generally of a rolling or level character, is in places deeply decomposed, and the dark-red clay soil generally contains unaltered bowlders from the tuff-breccia embedded in it.

The lower southwestern part of the quadrangle is characterized by a great abundance of volcanic sands and tuffs alternating with tuff-breccia and here and there containing smaller bodies of gravel, locally auriferous. This is probably explained by the fact that a broad river basin existed in this vicinity, in which the volcanic material was frequently worked over between the eruptions. The channels of the intervolcanic epoch, which contain little or no gravel, are usually found to be completely filled with tuff-breccia. Here, as well as in other parts of the quadrangle, the last and the heaviest flows consist of the same tuff-breccia.

The following sections show accurately the composition of the lava cap covering the gravel at several points on the Forest Hill divide. They have been obtained chiefly in the shafts sunk through the volcanic cap to reach the underlying gold-bearing gravels.

Section at Gray Eagle shaft.

	Feet.
Andesitic tuff-breccia	130
River wash, sand, and gravel, largely volcanic	110
Andesitic tuff	60
Gravel and sand	10
Andesitic tuff	20
Gravel	7
Andesitic tuff	25
Gravel	2
Bedrock.	
	364

At this place there are thus four distinct strata of volcanic material separated by strata containing river wash. The pebbles in the gravels are mainly of volcanic origin, but most of the gravels contain a little gold.

Section north of New York Canyon, near Iowa Hill.

	Feet.
Andesitic tuff-breccia	90
Auriferous gravel	4
Andesitic tuff	160
Auriferous gravel	60
Bedrock.	
	314

Section at Reed mine, Deadwood.

	Feet.
Andesitic tuff-breccia	70
Gravel with a little gold	7
Andesitic tuff	40
Gravel	6
Andesitic tuff	30
Brown tuffaceous clay ("chocolate")	5
Auriferous gravel	3
Bedrock.	
	161

The section at the Reed mine is characteristic for a considerable extent of country in the vicinity of Eldorado Canyon, Deadwood, and Last Chance.

DETAILED DESCRIPTION OF AURIFEROUS GRAVELS.

TERTIARY PREVOLCANIC GRAVELS.

OREGON CREEK AND VICINITY.

Along Oregon Creek several bodies of gravel are exposed, lying on flat benches, some of which are less than 100 feet above the stream. The gravels at Tippecanoe are 100 feet thick and consist of quartz and chert pebbles, many of them imperfectly washed. They contain no

volcanic rocks. The course of the Tertiary stream must, as shown by the bedrock relations, have followed the present Oregon Creek. The gravel at the Remargis and Gales diggings, 2 miles farther up the creek, is similar. At Tippecanoe (bedrock elevation 3,555 feet) a few acres have been hydraulicked. Some work has also been done at Gales; the gravel is here 50 feet thick and is covered with 10 feet of pipe clay.

NORTH COLUMBIA.

A junction of two important streams took place near North Columbia, and here the auriferous gravels are developed to a greater extent than at any other place. In the Smartsville quadrangle there is a large area of gravel extending from Badger Hill to the quadrangle boundary. This continues in the Colfax quadrangle as far east as North Bloomfield, covering about 8 square miles. There is doubtless a deep channel with slight grade running from Grizzly Hill (1 mile southwest of Kennebec House) to Badger Hill, where it was joined by the steeper channel of North Bloomfield from the east. The gravels at North Columbia are among the most extensive and deepest known, the depth along the center of the channel being from 400 to 500 feet. The gravel in the deepest trough exposed at Badger Hill and Grizzly Hill is coarse and made up largely of metamorphic rocks; the top gravel, spread out over the benches, is fine and much more quartzose. Near the surface, especially up toward the base of the lava flow, there are heavy masses of sand and light-colored clays.

The gravels at North Columbia are owned chiefly by the Eureka Lake Co., whose claims cover an area of 1,445 acres along 2½ miles of channel. A large amount of surface work has been done, and 150 feet of gravel has been washed off. The deep part of the deposit exposed at Grizzly Hill can be reached only by running long and expensive bedrock tunnels; this would have been done but for the injunctions against hydraulic mining. It is estimated that 25,000,000 cubic yards have been washed off and that 165,000,000 cubic yards remain. (See Pls. III, p. 20; XXIII, *A*, p. 144.)

NORTH BLOOMFIELD, DERBEC, AND RELIEF.

At North Bloomfield the exposures are excellent in the hydraulic bank along the center of the channel. The bedrock rises north and south of the main channel. Across the bottom it is nearly level for 300 or 400 feet. The deepest gravel is 130 feet thick; this is capped by heavy bodies of light-colored clay and sand interstratified with fine gravel, and here and there near the top also with andesitic tuff; the clay and sand may reach 150 feet in thickness. This material is in turn covered by 600 feet of tuffaceous breccia. The lower surface of the breccia is uneven, as shown by the fact that sand and clay outcrop a short distance east of the Derbec mine. About a mile north of North Bloomfield the channel forks again below the lava. One of the main forks has its inlet from the lava ridge north of Backbone House, where the configuration shows the existence of a deep channel, along the center of which Bloody Run has excavated its canyon. Gravels capped by heavy masses of sliding clay are here exposed.

Hydraulic mining has been carried on at North Bloomfield on a very large scale. The excavations extend for 5,000 feet and are 500 to 600 feet in width, with banks as much as 500 feet in height. The deposit has been opened by a bedrock tunnel 7,874 feet long, starting from Humbug Canyon. The sum of $3,000,000 is said to have been expended on this tunnel, the water supply, and other preliminary work. Shortly after the completion of the tunnel hydraulic mining was suspended by injunction of the courts, and since then the only gravels worked by the hydraulic process have been those the tailings from which could be impounded before reaching the river. Some drifting has been done, but the deep gravels are not rich.

The average yield per cubic yard is from 4 to 10 cents. Most of the value is contained in the deep gravels (130 feet), and in these the richest parts are the first few feet above the bedrock. Some portions of the clay and sand near the top are almost barren. Owing to the great width of the channel the gravel next to the bedrock is rarely rich enough for drifting. The yield of the mine from 1866 to 1900 was approximately $3,500,000. About 30,000,000 cubic

yards has been excavated, and 130,000,000 cubic yards is said to remain. The same amount may be available in the vicinity of Lake City.

Mining operations from the Derbec shaft have proved the existence of a deep channel extending for several thousand feet eastward. The Derbec channel, which has a steep grade, has been mined upstream from the shaft for a distance of 7,000 feet, following the curves; the width of pay gravel was from 150 to 600 feet and the height 8 to 16 feet from the bedrock. The gravel is coarse, with many bowlders, some of which are of granite. The average value per ton is $2.47. The mine was in operation from 1877 to 1893, and the production in some years reached $200,000.

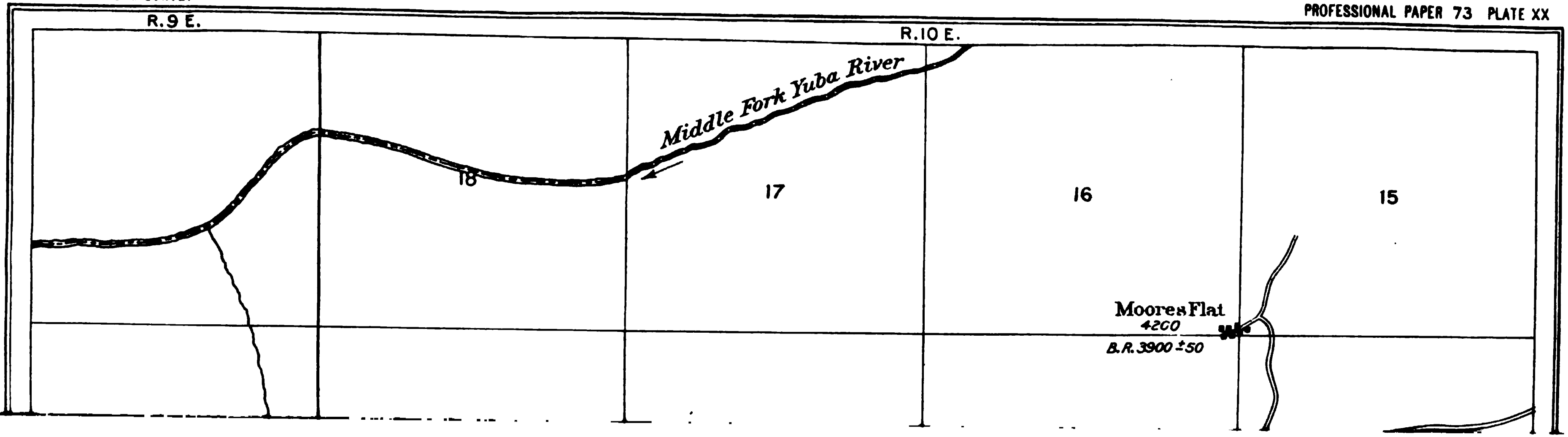
There can be little doubt that the Derbec channel continues toward Relief. At Relief erosion has exposed a deep trough in the old bedrock and about 200 acres of auriferous gravels. The oldest gravels, as usual coarser and containing less quartz, are 60 feet deep and are covered by 100 to 200 feet of alternating sand, fine quartz gravel, and clay. Some hydraulic work was done long ago at the southern and eastern rims of the channel, but for many years drifting operations only have been carried on. The Union tunnel, about 2,500 feet long, has been driven from the southwest side of the gravel area, and amounts up to $30,000 and $40,000 a year have been produced for a number of years. Drifting has also been done from the Blue Lead and the Waukesha tunnel, started from the northeast side of the deposit.

Plate XX explains the Derbec and North Bloomfield operations and is based on a map kindly placed at the disposition of the Geological Survey by Mr. A. D. Gassaway. In 1901 the Union Blue Gravel Co., under the management of Mr. Gassaway, started a tunnel in Humbug Canyon above North Bloomfield, and on its completion began the mining of the Derbec channel upstream from the point where the Derbec Co. left it. The operations were very successful until an area of granitic rocks was encountered underneath the lava; the channel spread out at this point, and the gold values consequently became less concentrated.

The first three bedrock figures to the left on Plate XX mark the North Bloomfield channel, as exposed by hydraulic work or drifting. The grade here is 100 feet to the mile; the direction southwest. From the point marked "2979" to the deep ground found in the Last Chance incline, south of North Bloomfield, the direction is northwest and the grade only 67 feet to the mile. The channel was next found at the Derbec shaft, where the bedrock elevation is 3,349 feet, or about 300 feet higher than at Last Chance, the distance being about 1¼ miles and the stream flowing south. It appears now that the Derbec and North Bloomfield channels must be identical. In a former publication [1] the writer has expressed doubt concerning this, but the bedrock relations are such that no other connection seems possible. The difficult question is how to account for this abnormal grade between the two points in which the channel has been opened. It has been suggested that a fault exists here underneath the covering formation, and this will probably be found to be true. The Derbec channel has been mined for 1¼ miles in a general west-southwest direction, and found to have a grade of 131 feet to the mile. On the slope toward Bloody Run, north of Backbone House, there is an inlet of a large channel similar in its general characteristics to the North Bloomfield channel; the bedrock elevation of this inlet is not established with certainty on account of landslides which obscure the relations, but in the publication just cited it is assumed that this is the real upstream continuation of the North Bloomfield channel, and that from this point it curved out and has been eroded over the present river canyon to reappear at Woolsey Flat and Moores Flat. The grade from the Derbec shaft to this inlet would be about 50 feet to the mile, the direction being south-southeast.

This view is opposed by Mr. Gassaway and others, who point out that a deep depression has been found at the Watts shaft, between Derbec and Moores Flat. The collar of the vertical Watts shaft has an approximate elevation of 4,262 feet; the shaft is 417 feet deep; a crosscut was run due west from it at the bottom level for 1,260 feet, and two winzes were sunk about 50 feet deep to bedrock. At the bottom of the shaft and at the breast this crosscut was in bedrock, and the presence of a deep trough was thus established. The gravel is reported to be too

[1] Lindgren, Waldemar, Two Neocene rivers of California: Bull. Geol. Soc. America, vol. 4, 1893, p. 273.


R.9 E.
R.10 E.
Middle Fork Yuba River
18
17
16
15
Moores Flat
4200
B.R. 3900 ±50

poor for drifting operations. For 200 feet from the surface the shaft is said to be in volcanic material; the lower 200 feet is in pipe clay and fine gravels.[1]

The distance between the end of the Derbec workings and the Watts shaft is about 2 miles, the direction of the stream having been southwest. The difference in elevation is 266 feet, or a grade of 133 feet to the mile—almost the same as that of the Derbec channel. The elevation of the bedrock at Moores Flat is somewhat uncertain. Pettee gives 4,019 feet, and for Woolsey Flat 3,890 feet. On the whole it seems more probable that the main channel followed the present Yuba River, as indicated, and that a minor channel extended up toward the Watts shaft from Derbec. The question can not be said to be finally determined.

That a direct connection existed between Relief and the Derbec channel is certain, and the whole distance, 2½ miles, will probably be drifted. The direction of the channel is west-northwest, and the grade is accordingly not so steep; it averages only 60 feet to the mile.

MOUNT ZION.

For a long distance east of Relief the bedrock keeps high and no gravel occurs along the contact. But at Mount Zion, at Devils Canyon, fine quartz and gravel having a thickness as great as 50 feet appears below the North Bloomfield ditch for a distance of nearly a mile. Some little hydraulic work as well as drifting has been done here. Many years ago the main tunnel running due west for 1,400 feet struck bedrock pitching west. It is probable that this gravel filled a tributary running northward and joining the Derbec channel.

CHERRY HILL AND SHANDS.

At Cherry Hill, between Shands and Mount Zion, there is a small body of gravel below the North Bloomfield ditch. A few very small areas were noted at Shands; the largest was 100 feet thick, composed of well-washed pebbles and covered by subangular gravel. The small patches north and south of Graniteville are also partly subangular gravel. Well-washed gravel appears below the andesite north of the town but is thin and irregular. A small, steeply rising channel probably continues for some distance below the lava.

SNOW POINT, ORLEANS, AND MOORES FLAT.

At Snow Point and Orleans there are small bodies of auriferous gravel, the bedrock rising steeply southward. At both places the gravels have been nearly exhausted by hydraulic mining. A little drifting has also been done at Snow Point, where the bedrock elevation is 4,211 feet. At this place the bank is 135 feet high. The lower 15 feet consists of coarse gravel, which is covered by 90 feet of fine, sandy quartzose gravel, in turn overlain by 20 feet of clay. At Orleans (bedrock elevation 4,100 feet) the gravel was also largly quartzose. West of Orleans is Moores Flat (bedrock elevation 4,010 feet), where a considerable body of gravel is exposed. The gravel is of the same character as that at Snow Point, is from 100 to 130 feet thick, and is covered by andesitic breccia. Bowlders of quartz from 2 to 6 feet in diameter are found on the bedrock. It is estimated that 26,000,000 cubic yards have been washed off and that perhaps 15,000,000 yards remain. (See Pl. II, *B*, p. 20.)

WOOLSEY FLAT.

At Woolsey Flat there is likewise a large body of gravel exposed. The heavy gravel, 100 feet thick, is similar in character to that just described, but it is covered by as much as 150 feet of clay (bedrock elevation 3,890 feet). In all these gravel bodies the gold on the bedrock is rather coarse. But little workable hydraulic gravel remains at Woolsey Flat, as the height of the clay and tuff banks increases rapidly. The production of the hydraulic mines near Moores Flat and Snow Point, though very large, is not definitely known. None of them have been in operation since 1886.

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[1] Pettee, in Whitney's "Auriferous gravels," p. 400.

MINNESOTA, CHIPS FLAT, AND ALLEGHANY.

The most probable course of the old channel is, as indicated on Plate I (in pocket), approximately parallel to that of the modern river. Somewhere near Orleans the old river was joined by the Forest tributary, continuously traceable by way of Minnesota, Chips Flat, Alleghany, and Forest. At no place along this old tributary are any considerable bodies of gravel exposed. At Minnesota a small amount of hydraulic work has been done and about 20 feet of fine quartz gravel, mixed with larger bowlders of the same material, is exposed. The gravel is coarsest on the bedrock. The bedrock elevation is 4,220 feet. The channel extending below the lava to Chips Flat is said to have been drifted along its entire length and to have been very rich. At Chips Flat (bedrock elevation 4,235 feet) are a few acres of exposed gravel, the banks of which show a few feet of coarse gravel with well-washed quartz bowlders near the bedrock, 30 feet of fine gravel, 30 feet of clay, and above this the volcanic capping. A few smaller patches of gravel are exposed on the same ridge, the largest of which, east of Chips Flat, is called Balsam Flat.

SMITHS FLAT.

The continuation of the Minnesota channel is found a mile south of Alleghany, at Smiths Flat, somewhat higher in elevation than Chips Flat. Here also a little hydraulic work has been done, and the banks are 50 feet in height. From this point the channel has been drifted through to Forest. As usual, in this channel the bottom gravel is coarse and contains many flat cobbles and bowlders of a bluish-white siliceous slate; also much quartz. The gold on the bedrock is coarse and has in places worked its way down some distance into the decomposed bedrock. The production of this channel has amounted to several million dollars, but it is impossible to obtain exact statistics. One of the most successfully worked claims from 1855 to 1863, inclusive, was the Live Yankee, extending along 2,600 feet of channel. Its production was nearly \$700,000.

FOREST.

A small amount of heavy gravel is exposed at Forest (bedrock elevation 4,500 feet), but the channel enters the northern ridge immediately and continues in a north-northeast direction. It was worked by the Bald Mountain Co. from 1872 to 1879 or 1880 for a distance of about a mile, producing \$150,000. The gravel was extracted to a height of 3½ feet, including 1 foot of bedrock. The yield per cubic yard of unbroken gravel was about \$7. A shaft sunk 1,800 feet from the mouth of the tunnel shows 215 feet of clay and sand covering 15 feet of gravel; no such heavy masses of silt are found farther down on this channel. The Bald Mountain channel was found to be cut off by a lower, intervolcanic channel filled with lava, but continuous beyond this toward the Ruby mine, in the Downieville quadrangle.

The North Fork Co. has a long tunnel running in a northwesterly direction for more than a mile and some good drifting ground. This tunnel is probably on a tributary to the main channel. The Bald Mountain Extension Co. for some years worked a branch of the Bald Mountain channel by means of a tunnel 1½ miles long, running northwestward under Bald Mountain. Later operations were transferred to a tunnel at the head of Kanaka Creek, in the Downieville quadrangle. This channel is also cut by a lower, intervolcanic channel. At the Ruby mine both an older and a more recent channel have been worked. Small drifting operations have been carried on at several points on the ridge west of Alleghany.

AMERICAN HILL.

To return now to the main old channel, which has been traced as far as Snow Point, its continuation is without much doubt to be found at American Hill and Bunker Hill, on Wolf Creek. At American Hill and for a mile westward around the head of Little Wolf Creek bench gravels occur. At Bunker Hill, on the east side of Wolf Creek, a mass of gravel about 300 feet thick, covered by clay and sand, lies in a deep trough in the bedrock, the elevation of which is 4,725 feet. It is believed that this channel extends in a northwesterly direction

under the lava. Two long tunnels, now inaccessible, were driven some time ago. They are said to have shown the existence of two channels at considerably different elevations. The reports do not agree as to whether they would pay for drifting.

BLUE TENT.

We now return to the western edge of the quadrangle in order to trace the southern branch of the main stream. At Blue Tent, on the south side of the South Fork of Yuba River, the gravel appears extensively below the lava, filling a deep trough in the bedrock, the deepest part having the same elevation (2,483 feet) as Grizzly Hill, across the canyon. The bottom gravels are 25 feet thick, coarse and cemented, and is covered by over 300 feet of light-gray sand and clay mixed with fine quartz gravel. The sand is particularly abundant and nearly barren. About 15,000,000 cubic yards has been removed and some 90,000,000 yards remain, much of which is barren clay and sand. The lower gravel averaged 15 cents or more to the cubic yard, but the sandy top gravel contained only 2½ cents. It is stated that the hydraulic operations were not remunerative. The bottom of the channel is reported to be 1,000 feet wide and the gravels of low grade. Even the 5 feet of gravel next to the bedrock did not contain more than 50 cents a ton, it is reported. Nevertheless, it is probable that some attempt will be made to open the channel from Blue Tent to Scotts Flat.

QUAKER HILL AND SCOTTS FLAT.

On the ridge northeast of Nevada City a small but rich channel has been drifted from the East and West Harmony inclines. The gravel, which is partly subangular, is taken out to a depth of 4 feet. In Rock Creek lie large masses of clay and sand similar to the deposits at Blue Tent. Still larger accumulations are exposed at Scotts Flat and Quaker Hill. The gravel, which is covered with rhyolitic tuff and andesite, fills a deep trough well exposed by Deer Creek and Greenhorn River. Along the principal channel the gravels are nearly 600 feet deep; the bench gravels surrounding the deepest trough are about 300 feet in depth. At Hunts Hill the deepest channel is exposed by mining operations at about the level of the tailings in the river at an elevation of 2,620 feet. North of this point it is not visible until exposed again at Blue Tent. The geologic evidence clearly shows that the deep channel is continuous from Hunts Hill to Blue Tent. A shaft has been sunk in the old diggings at Quaker Hill and a bedrock was found at an elevation of about 2,650 feet. A shaft sunk in the creek at Scotts Flat struck bedrock at an elevation of about 2,770 feet, the lowest bedrock not being found. At Quaker Hill the width of the channel said to pay for drifting is about 130 feet, and the depth of pay gravel is from 4 to 16 feet. As usual, the gravel is coarse and cemented in the deep trough, and the bench gravels, several hundred feet thick, consist chiefly of fine quartz gravel mixed with sand.

The yield of the top gravel rarely exceeds 6 cents a cubic yard in fine gold, the size of a pinhead or less, but the bottom gravel may be very rich. It is estimated that near Scotts Flat 12,000,000 cubic yards has been removed and that 35,000,000 yards has been worked at Quaker Hill, where the gravel banks reach a thickness of 250 feet. A vast amount of workable gravel, estimated at 140,000,000 yards, remains at Quaker Hill. At both Quaker Hill and Scotts Flat it is difficult, if not impossible, to obtain dumping ground and sufficient grade for sluices.

Deep gravels fringe the rhyolite for 3 miles east of Quaker Hill and represent without much doubt a tributary crossing the ridge near Central House (Galbraith). South of this place there is about 100 feet of clay underlain by some gravel. Here some drifting has been done on both the north and the south side. Heavy clay masses are exposed at Burrington Hill, where some hydraulic work was done long ago. The gravel of this tributary has also been hydraulicked on the north and south sides of the Quaker Hill ridge.

High bedrock appears on the ridge 3 miles northeast of Quaker Hill. East of this are exposed the small Red Diamond channel on the north side of the ridge and other channels

covered with deep clay on the south side. A little work has been done on all of them. It is said that at Coopers Mill an old incline was sunk on the rim, tracing the bedrock down to an elevation of 3,500 feet. If this report is correct it is highly remarkable, as this elevation is considerably lower than the rim rock at any other point in this lava area and would imply the existence of a closed basin. The important Centennial-San Jose channel is covered by this same lava area. Buckeye Hill is a small mass of bench gravel southeast of Quaker Hill. The gravel has been almost entirely removed.

YOU BET AND LITTLE YORK.

At Red Dog and Hawkins Canyon, near You Bet, the deep channel has again been exposed and is beyond doubt continuous between the two points. The gravel is similar to that of Quaker Hill. The deepest gravel has been hydraulicked only at the places mentioned, but considerable drifting by means of tunnels and inclines has been done from Niece & West's claims for 1½ miles northeast, on the Steep Hollow side. The channel has very little fall, the average elevation being 2,620 feet. Over a part of the distance where the direction of the river was northeasterly the grade is reversed. It is estimated that 47,000,000 cubic yards of gravel has been removed, leaving over 100,000,000 yards available. Much of this, however, would be difficult to wash on account of lack of grade. Reports of yield and grade of level are not available, but the You Bet diggings have probably produced $3,000,000.

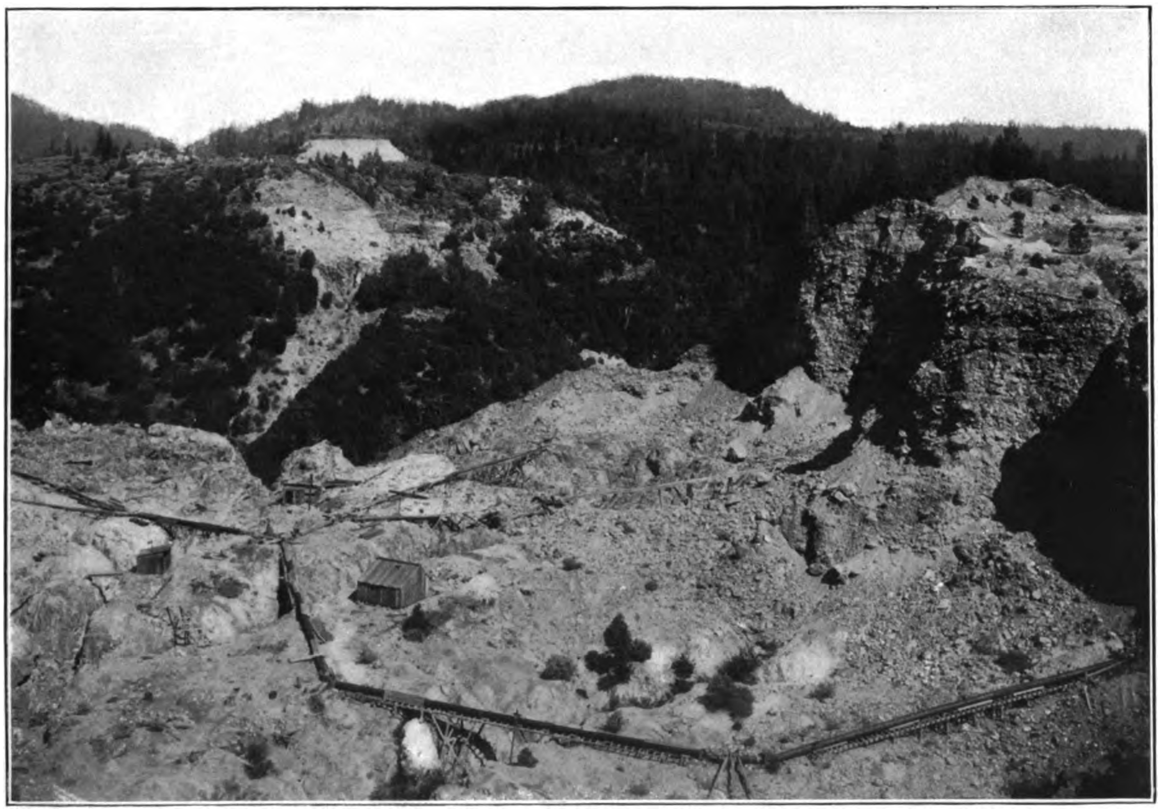
The Little York gravel area contained a fragment of the old deep channel which has been almost completely removed by hydraulic mining. (See Pl. XXIII, *B*.) The character of the gravel is similar to that at You Bet. As usual, the narrow, deep channel contains a hard, cemented gravel, 30 or 40 feet thick, capped by as much as 350 feet of fine gravel interstratified with some clay and sand. The bedrock elevation is 2,706 feet. Large bowlders of quartzite and quartz occur on the bedrock, both in the deep channel and on the benches. The yield has probably exceeded $1,000,000.

DUTCH FLAT.

The continuation of the deep channel is found at Dutch Flat, and its direction is plainly marked by the small intervening bodies of Missouri Hill and Eastman Hill. The principal area at Dutch Flat extends east and west for a mile; the gravel has a maximum depth of about 300 feet, the lower 150 feet consisting of coarse blue gravel, made up largely of metamorphic rocks, well cemented and covered by a varying thickness of finer quartz gravel, clay, and sand. (See Pl. XXI.) In the lower gravel and on the bedrock heavy bowlders are plentiful. The channel has a very strong grade, in marked contrast to the level stretch below You Bet. This is caused in part by the later tilting of the range, but in part is the natural result of the river breaking through the hard gabbro of the Serpentine belt. Hydraulic work has been done chiefly at the eastern end at the Polar Star mine (bedrock elevation 3,075 feet) and at the western end, or Thompson Hill (bedrock elevation 2,848 feet), at both of which places the deep bedrock is exposed. At the Polar Star diggings (Pl. XXI, *B*), a short distance east of Dutch Flat, some hydraulic work has been done in recent years. Little Bear Creek flows about 400 feet below the mine. The channel forms a distinct trough 200 feet wide. The bedrock is in part polished and hummocky, in part soft and decomposed. The well-cemented gravel consists of cobbles averaging at least 8 inches in diameter. It contains many bowlders, in part poorly washed; some of them are 8 or 10 feet in diameter. There is very little sand and the grade is steep, the fall being 60 feet in 600 feet to the well pit in which the gutter is exposed. About 90,000,000 cubic yards has been washed and a considerably less amount remains. Practically the whole extent of the channel has been drifted and the cemented gravel worked in stamp mills. The yield is not known but probably exceeds $3,000,000. The Polar Star hydraulic gravel is said to average 11 cents to the cubic yard.

A. VIEW LOOKING NORTH FROM ROAD JUST SOUTH OF DUTCH FLAT, PLACER COUNTY.

The white streak in the middle is washed gravel of the main channel, the bottom of which lies 100 feet below the point of observation. Slate ridges of Camels Hump in the distance. Photograph by J. C. Hawver. See page 144.

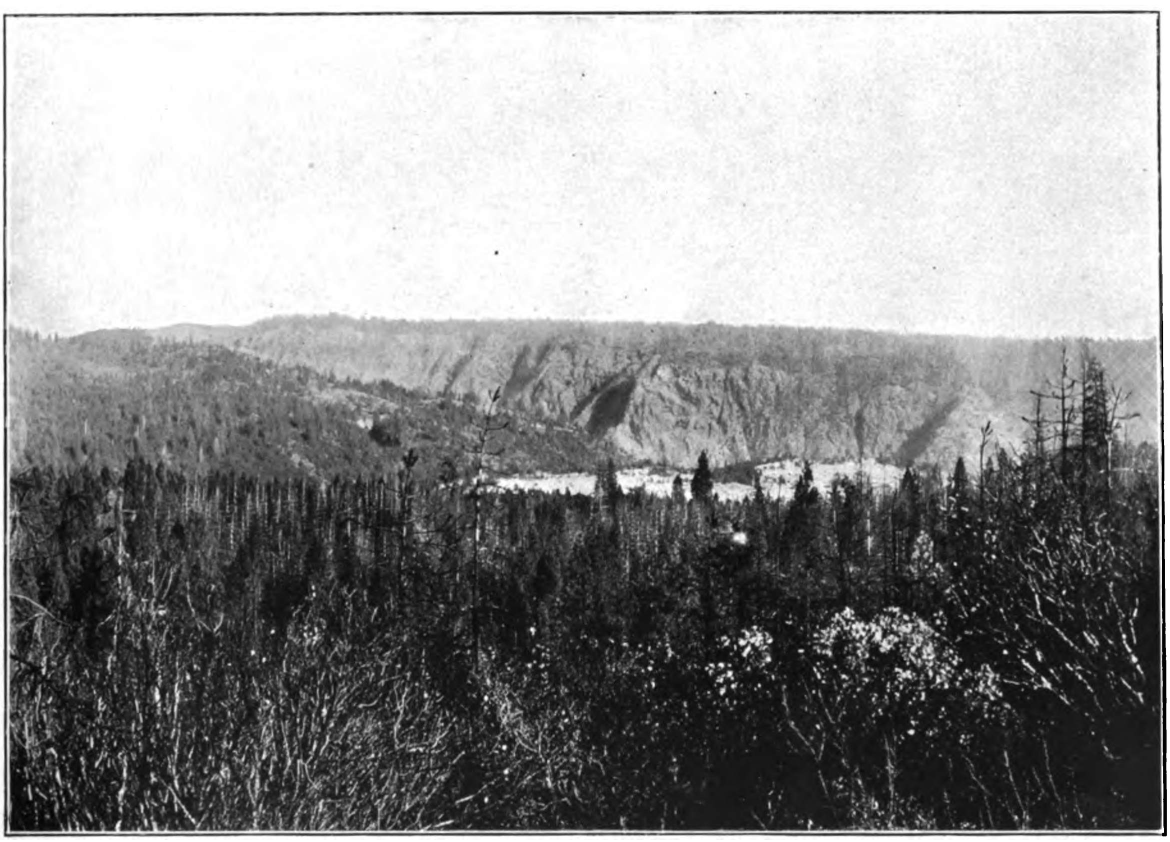


B. HYDRAULIC PIT OF POLAR STAR MINE, PLACER COUNTY.

Showing deep channel with coarse gravel. Fine quartzose bench gravel is seen in the distance several hundred feet higher. Photograph by J. C. Hawver. See page 144.

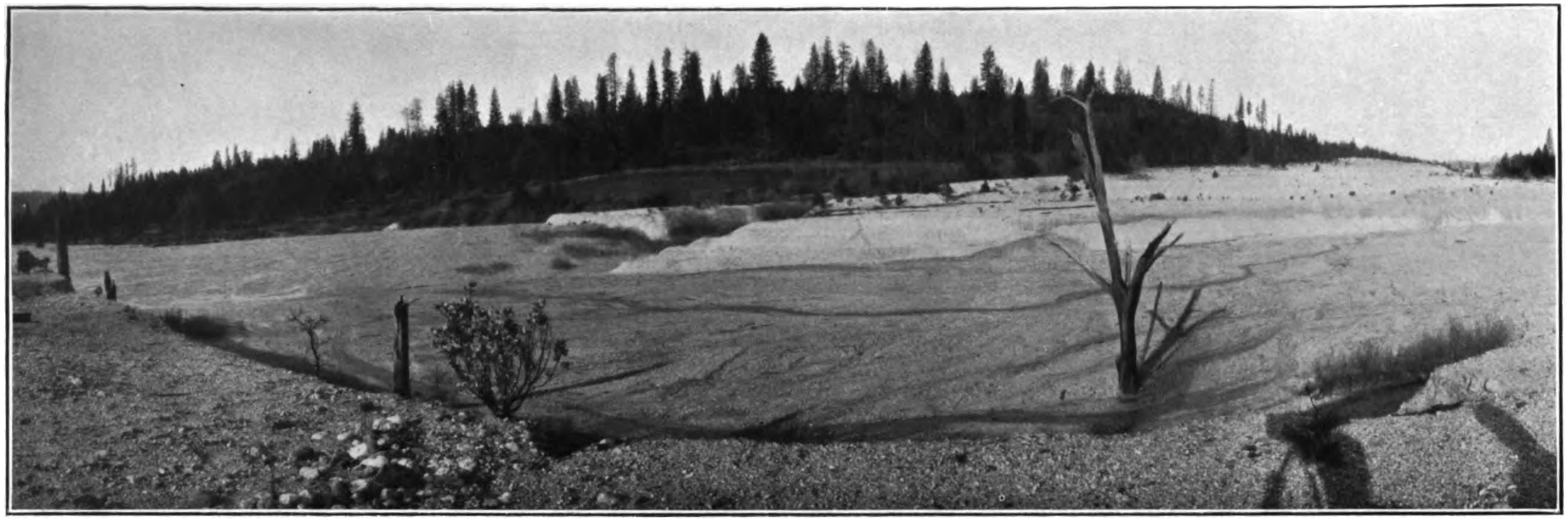
A. VIEW LOOKING NORTHEAST FROM A POINT NEAR IOWA HILL, PLACER COUNTY.

Showing canyon of North Fork of American River. Independence Hill in the middle foreground. Gravels of Indiana Hill to the left, across the river, the bedrock rising rapidly beyond toward Giants Gap. Photograph by J. C. Hawver. See page 148.



B. VIEW LOOKING EAST ACROSS DEEP CHANNEL OF INDIANA HILL FROM A POINT 1 MILE SOUTH OF GOLD RUN, PLACER COUNTY.

Deepest channel lies 100 feet below the white streak of washed gravels. Across the canyon of American River the bedrock nearly reaches the sky line but is covered by a thin flow of andesite. Giants Gap to the left. Photograph by J. C. Hawver. See page 145.



A. TAILINGS ACCUMULATED IN SPRING CREEK BELOW NORTH COLUMBIA, NEVADA COUNTY.

Photograph by J. C. Hawver. See page 139.

B. VIEW LOOKING NORTH FROM A POINT NEAR GOLD RUN, PLACER COUNTY.

Little York, You Bet, and Chalk Bluffs in the middle distance. Banner Hill in the background. Photograph by J. C. Hawver. See page 144.

INDIANA HILL AND GOLD RUN.

From Dutch Flat the gravel area continues southward, narrowing to a few hundred feet at Squires Canyon and widening to 3,000 feet near Gold Run; its south end, overlooking the North Fork of American River, is called Indiana Hill. Over a large part of Indiana Hill the gravel is deep, reaching in places 300 feet or even a maximum of 400 feet. Plates XXII and XXIII show well the contrast between the deep canyons and the more gentle slopes of the Tertiary valley; the present slopes from the gravel areas (showing white) to the ridge summits practically represent the Tertiary configuration.

The upper gravel at Gold Run consists of closely packed, thoroughly well rounded pebbles, of which about one-third are quartz and the rest chiefly soft and decomposed material. In places it contains large chunks of white clay that looks somewhat like a rhyolite tuff. Fossil wood is locally abundant. Fine fluviatile bedding is seen here and there, as illustrated in Plate XXIV, *B* (p. 150). The bottom gravel in the deep trough at Indiana Hill shows 60 feet of coarse, cemented blue gravel, with a large proportion of bowlders of metamorphic rocks. The lowest trough is from 300 to 500 feet wide. The question whether there is a deep and continuous channel from Indiana Hill to Dutch Flat is one of much importance. Deep bedrock has been found at Jehoshaphat Hill, half a mile south of Dutch Flat, having an elevation of 2,877 feet, this part of the channel clearly connecting with Thompson Hill, a short distance northward. In Squires Canyon, where the gravel area narrows to 500 feet and the elevation is about 3,050 feet, a shaft is stated to have been sunk to a depth of about 150 feet, striking pitching bedrock at that depth and showing the existence here of a deep trough having an elevation of less than 2,900 feet. If this is correct there is little doubt that a continuous deep channel exists between Indiana Hill (elevation 2,792 feet) and Dutch Flat, with a moderate grade of 25 feet to the mile toward Indiana Hill. Bedrock has been exposed 1,200 feet farther north by the Cedar Creek tunnel, and 2,000 feet from Indiana Hill by a tunnel from Canyon Creek, run by the Gold Run Ditch and Mining Company. From the former place the bedrock is said to slope gently toward Indiana Hill. The so-called Forty-nine shaft was sunk nearly to the bottom of the channel between Gold Run and Indiana Hill, but exact data regarding its elevation are not available. Another shaft, 75 feet deep, was sunk to the bedrock in Canyon Creek about halfway between Gold Run and Dutch Flat. Extensive hydraulic mining operations were carried on at Gold Run for about 10 years, in which time perhaps \$3,000,000 or more was extracted. Some 84,000,000 cubic yards has been washed off, but a larger quantity, estimated at 92,000,000 yards, remains. An area of 555 acres has been washed off to an average depth of 75 feet. At Indiana Hill, where the bedrock elevation is 2,792 feet, the bottom gravel was drifted and crushed in mills. The yield per cubic yard of hydraulic gravel is said to be 11 cents. Between 1872 and 1874 the drifting ground at Indiana Hill yielded at the rate of \$9 to the cubic yard of gravel in place.

ALTA.

Above Dutch Flat, toward Alta, is the gravel hill of Nary Red, the narrow channel of which has been drifted and hydraulicked; the gravel is a medium-fine red quartz, covered with rhyolitic clays. The bedrock elevation is 3,300 feet. From this point a channel extends in the hill toward Alta. A shaft sunk at Alta 35 feet below the railroad found bedrock at 132 feet. A tunnel extends from Canyon Creek, half a mile south of Alta, to the shaft, and the gravel in the channel is now being worked. The gravel is soft, quartzose, and not cemented. From this point a branch channel probably crosses Canyon Creek and extends to Moody Gap, east of which the remainder is probably eroded. Another branch extends from Alta eastward, probably emerging at Shady Run and having a grade of 100 feet to the mile westward.

SHADY RUN.

An old channel of considerable importance appears below Shady Run underneath a heavy capping of rhyolitic tuff and andesitic tuff breccia. The place appears to be an inlet and the channel, which probably came down from Lost Canyon, a few miles to the west, is likely to continue below the lava down to Alta and Dutch Flat. The channel lies in a well-defined depression and has been traced by the present workings for about 2,000 feet. It is up to 400 feet wide and contains from 4 to 70 feet of well-washed quartz gravel. The pay streak, as a rule, occupies only a part of the depression and the gravel is reported to run from 50 to 90 cents a ton. Outside of the pay streak it averages 45 cents. The gold is coarse and its fineness is 950. The channel was first exposed at Blue Bluffs and the Cedar Creek claim, half a mile north of Shady Run and 313 feet below the railroad station. The elevation is 3,849 feet. It was both hydraulicked and drifted at this point, the drifting being done in 1896. Next it was exposed in the Live Yankee hydraulic cut. The Cameron tunnel, run in at this point, found steeply rising bedrock to the west of the cut. The Haub tunnel is driven southward at an elevation of about 3,810 feet, northeast of Shady Run station, and the channel has here been drifted for a width of 400 feet. It is believed to turn due west from this point and enter the ridge below the railroad. The channel thus runs west from the inlet at Cedar Creek, then turns south, and at the Haub tunnel changes to west again.

Many people believe that the channel is only partly exposed at Cedar Creek and that its main part continues up toward Blue Canyon under the lava. The only evidence supporting this view seems to be derived from the exposures at the Talbot tunnel. This was started in bedrock 200 feet below Shady Run station, and thence run north in rhyolite tuff for 1,100 feet. A shaft was sunk to bedrock, finding it 150 feet below tunnel level but still pitching. The elevation of this bedrock was 3,822 feet. These facts are, however, also explainable on the supposition that the channel curves northwest from Cedar Creek diggings and that a smaller tributary joins it from the side of the Shady Run and Blue Canyon ridge.

It would seem that the Alta and Shady Run channel should pay for drifting on a large scale.

BLUE CANYON.

The Azalea tunnel is driven in a northerly direction for 3,300 feet from a point 2 miles southwest of Blue Canyon and 589 feet below the railroad track, at an elevation of approximately 3,800 feet, the purpose being to open a channel supposed to underlie the volcanic ridge. The extension of the tunnel would strike a little above the point where the Towle Railroad crosses Canyon Creek. At the end of the tunnel an upraise of 350 feet was made in slate. The tunnel is evidently too low. If a channel exists underneath the ridge above Shady Run it is probably only a smaller branch, as the main inlet is clearly located at Shady Run.

There is evidence of a channel 60 feet below O'Rell station, 2½ miles below Blue Canyon, and a little gold has been taken out from a tunnel close by.

A remainder of the same channel is preserved at Lost Camp, 2 miles south-southeast of Blue Canyon. Here are about 120 acres of quartzose, imperfectly washed gravel, 50 to 75 feet deep, containing some rather large bowlders. Only a small portion of this gravel has been hydraulicked.

LIBERTY HILL AND LOWELL HILL.

A branch of the Dutch Flat channel continued across the present Bear River. Elmore Hill, on the point between Bear River and Little Bear Creek, has been almost completely washed off. Rising at a rapid rate the continuation of the channel is found at Liberty Hill (bedrock elevation 3,349 feet). The gravel is here about 60 feet deep, 30 feet of reddish quartz gravel covering the same amount of blue gravel, full of very large bowlders of gabbro and serpentine. The amount of gravel removed is estimated at 2,000,000 cubic yards, some 16,000,000 yards remaining. The channel continues up to Lowell Hill, but the gravel here is

covered by very heavy masses of light-colored clay. At Lowell Hill (bedrock elevation 3,829 feet) the gravel is 30 feet deep, the coarse bottom gravel being covered by finer quartzose gravel. The heavy clay banks make hydraulic working difficult. Considerable work has, however, been done at the Planet mine. Drifting operations have also been undertaken with some success south of Nigger Jack Hill, at the Valentine mine, and farther south opposite the Planet at the Swamp Angel.

REMINGTON HILL AND STEEP HOLLOW.

Opposite Lowell Hill lies Remington Hill, at a slightly higher elevation (bedrock elevation 3,869 feet). Here, also, is an old depression filled with gravel, of which a few acres is exposed. The gravel is similar to that of Lowell Hill and is capped by heavy masses of clay. The amount excavated is estimated at 1,750,000 cubic yards, while possibly 600,000 cubic yards remains. Much of this, however, is heavily capped by clay and volcanic tuff. The channel has been found in two tunnels a little to the east, making it possible that the channel comes out again at Democrat, another little gravel point separated from Remington by a bedrock spur, where hydraulic work has also been done.

On the point between the forks of Steep Hollow, opposite Democrat, is the small gravel hill called Excelsior, doubtless representing the extension of the Democrat channel. To the north and northwest of Excelsior the bedrock rises steeply. The channel may have continued 2 miles or so farther northeast, but whether it enters under the lava flow or follows the present course of Steep Hollow is uncertain.

ALPHA AND OMEGA.

On the south fork of the Yuba several important gravel bodies are found. A few small points covered with quartz gravel occur southeast of Relief, on the south side of the canyon. At Alpha (bedrock elevation 3,852 feet) about 75 acres of gravel is preserved, the pebbles consisting chiefly of quartz, quartzite, and a hard conglomerate. Some quartz bowlders on the bedrock reach 5 feet in diameter, but most of the gravel is light and sandy. The banks are 90 feet high, including 20 feet of clay at the top. The amount removed is 5,000,000 cubic yards; only a fourth as much remains.

At Omega several hundred acres of gravel is exposed and has been extensively worked. The gravel lies on a flat bench (bedrock elevation 4,028 feet) and apparently extends southeastward under the lava. Its greatest thickness is 175 feet. The bed consists of 150 feet of gravel covered by 6 feet of clay, above which is 20 feet of gravel, all showing colors of gold. The lowest stratum contains some large bowlders of granite from the Canyon Creek area, but the main body is composed of smaller cobbles, up to 6 inches in diameter, quartz decidedly predominating. The extent of this channel southward is not definitely known, though a shaft was sunk to bedrock on the Blue Tent ditch, cutting good gravel; its depth is not known. Some distance south of Omega is a small gravel flat called Shellback, at a higher elevation; beyond this the bedrock rises steeply. Toward the southeast the bedrock also rises, though at a lower angle, and gravel is found in places along the rim. At Diamond Creek (bedrock elevation 4,206 feet) a small body of quartz gravel is exposed, having a maximum thickness of 12 feet, covered by a nearly barren Pleistocene morainal bowlder clay.

Extensive hydraulic operations have removed 12,000,000 cubic yards at Omega, the tailings being discharged in Scotchman Creek through a 3,000-foot bedrock tunnel. Apparently reliable calculations give 13½ cents as the yield per cubic yard, the lowest gravel, of course, being much the richest part of the deposit. About 40,000,000 cubic yards is estimated to be still available for hydraulic mining.

PHELPS HILL, CENTENNIAL, AND SAN JOSE.

There are many uncertain and puzzling features at Phelps Hill and the Centennial and San Jose shafts. At Phelps Hill, at an elevation of about 4,060 feet, 15 to 30 feet of gravel is

exposed below the lava for half a mile. Heavy quartzose bowlders are found on the bedrock. The gravel is cut by a fault which throws the west side down about 40 feet. The fault is traceable for at least 400 feet, running north and south. The Centennial shaft, 1⅓ miles south-southeast of Phelps Hill, was sunk in 1887 to a depth of 400 feet, and the bottom of a deep channel was found by drifting from it. Later a tunnel was run from a point south of Phelps, the elevation being about 4,080 feet. The channel was struck at the tunnel level; it is 400 feet in width and carries gravel of quartz and greenstones, the gold being fairly coarse. Work has been suspended, from which it may be inferred that on account of its width the gravel body on the bedrock is not very rich. If, as seems probable, this channel connects with that of Phelps, it must have very slight grade.

A mile southwest from the Centennial shaft is the San Jose shaft, sunk in the bed of South Fork of Deer Creek to a depth of 340 feet, giving the channel an elevation between 4,000 and 4,100 feet, which is stated to be somewhat higher than the Centennial channel. Drifting from the shaft showed the channel to be about 300 feet wide. The gravel is composed of cobbles of quartz and country rock and is about 7 to 15 feet thick; it is covered by 40 feet of clay, above which is lava. There is little doubt that this channel is continuous with the Centennial and that its grade is northward, making it a branch by way of Phelps Hill of the main stream from Relief Hill to Omega. It has been thought by some that this channel might continue to Remington Hill with a southerly grade. This appears unlikely, however, and it is scarcely possible that there should be a continuous channel between Phelps and Remington hills, for the channel at these two places certainly connected with different branches of the old Yuba River. A low divide probably separates the San Jose channel from Remington Hill and from the Quaker Hill drainage. It is also very unlikely that any of the channels under this lava area had any direct connection with Omega.

IOWA HILL AND WISCONSIN HILL.

We now return to trace the most southerly branch of the river from Indiana Hill across Iowa Hill and the Forest Hill divide. On the Iowa Hill and Forest Hill divides a small amount of gravel is exposed on the surface, but the channels preserved below the lava are rich and numerous.

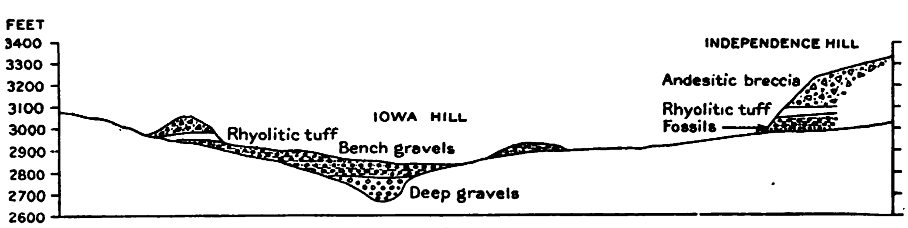


FIGURE 11.—Section across channel at Iowa Hill, Placer County, showing position of fossil leaves at Independence Hill. (See p. 56.)

At Iowa Hill a deep channel extends from northwest to southeast across the ridge north of Indian Creek. The sharply defined trough is 200 feet deep and is filled with coarse gravel, well cemented in its lower part (bedrock elevation 2,631 feet). The total thickness is over 300 feet. The channel is from 200 to 400 feet wide at the bottom. This gravel has been hydraulicked except a narrow ridge upon which the town stands. Lighter, quartzose bench gravels extend northeast of Iowa Hill. They have a maximum thickness of 200 feet and are covered by thin rhyolite tuff and andesite. (See fig. 11.) They have been extensively hydraulicked and some ground yet remains.

At Succor Flat a deep and narrow channel belonging to the intervolcanic epoch has been drifted for a distance of 2,500 feet; the same channel probably crosses Indian Creek at Monona Flat and finds its outlet at some place on Roach Hill. South of Indian Creek there are over 300 feet of gravels; farther south they thin out, with rising bedrock, but deepen again near Wisconsin Hill, having at both places the same general character as at Iowa Hill. Between Morning Star and Wisconsin Hill there is doubtless a deep and continuous channel, which is clearly the extension of that underlying Iowa Hill. Extensive hydraulic work has been done both near Morning Star and east of it along Indian Creek, as well as at Wisconsin Hill. A body of higher bench gravels across Refuge Canyon at Elizabeth Hill has also been hydraulicked, but nearly all of

this work has ceased during the last two decades. Instead, extensive drift mining has been carried on.

At the Morning Star the deep channel, extending in an easterly direction, has been mined for a distance of 3,000 feet; about 7 feet of cemented gravel is extracted, the width of the pay gravel being from 80 to 200 feet. The drift mine has proved among the richest. The gravel contained, for a long period, it is stated, $7 a carload, equal to $14 a cubic yard, and the annual production ranged from $25,000 to $150,000.

The Waterhouse & Dorn or Big Dipper mine has been working the same channel from 1890 to 1902 from the Wisconsin Hill side, with excellent results. The grade of the main channel is remarkably slight, 2,692 feet being the elevation of bedrock at Wisconsin Hill, 2,685 feet at the Morning Star, and 2,631 feet at the northwest side of the Iowa Hill channel. In 1899 the workings of this mine were connected with those of the Morning Star, proving conclusively the identity of the channels.

The bedrock is very uneven and hard, with many deep and often rich potholes. The gravel is coarse, with many bowlders, but is extremely well rounded. It is cemented with much granitic sand, indicating moderate grade, and is at many places noted to shingle northward. This tendency was observed long ago by J. B. Hobson in the Morning Star mine and goes to prove a northward course of the old stream. Several distinct benches, older than the deepest channel, have been mined, all of them on the east side, and up to 60 feet above the deepest trough. The gold is coarse. Along the steep east rim, high above the main channel, coarse and less well-washed gold is frequently found. A thickness of 5 or 6 feet of gravel is breasted, but the upper 3 feet usually contained but little gold. The yield in 1901 was about 135 carloads of 1 ton each in 24 hours. The average content was $6 a ton. Gravel carrying less than $2 a ton was not considered to pay.

The Jupiter drift mine has been worked with fair success during the last few years on a small intervolcanic channel finding its outlet on the southeast point of the Iowa Hill area of andesite tuff. The width averages 60 feet and the rims rise steeply.

A smaller channel pitching into the ridge has been followed for some distance from Grizzly Flat and probably joins the Morning Star channel. A small body of well-worked quartz gravel was found at Kings Hill, 1½ miles southwest of Wisconsin Hill; it is interesting because of its position between Yankee Jim and Wisconsin Hill and its comparatively low bedrock elevation (2,550 feet). Four or five acres of gravel has been washed here to a depth of 20 feet.

Above Monona Flat very little gravel was exposed, the andesite tuff resting on bedrock of irregular configuration. At the Giant Gap claim, 4 miles west of Damascus, the lava cap is very narrow; below it a gorgelike intervolcanic channel has been exposed. Three miles west of Damascus is McIntyre's claim, where a 1,000-foot tunnel has exposed the same or a similar narrow channel at an elevation of about 3,850 feet. A mile northeast of this is the Colfax claim, showing some quartz gravel (bedrock elevation 3,669 feet), probably belonging to a prevolcanic channel, the continuation of which may be found at Jimtown, three-fourths of a mile north of the reservoir. At Jimtown a shaft 100 feet deep has been sunk, finding quartz gravel and pitching bedrock.

No data are available to estimate the yield of the Iowa Hill divide since 1849. It probably considerably exceeds $10,000,000.

PECKHAM HILL AND TODD VALLEY.

We begin now a rapid sketch of the Forest Hill divide. A small part of its area falls south of the boundary of the Colfax quadrangle. At Peckham Hill a little unsuccessful drifting has been done on the deep and narrow intervolcanic "cement" channel (see p. 155) finding its outlet there at an elevation of 2,183 feet. At Todd Valley is a body of bench gravel which has been washed at Pond's claim until the overlying lava became too heavy to handle. This gravel is partly cemented, poorly washed, and about 40 feet thick. About 11,000,000 cubic yards has been washed off, the yield of which is given as $5,000,000, but this may be too high.

GEORGIA HILL, YANKEE JIM, AND SMITHS POINT.

At Georgia Hill, opposite Yankee Jim, a thickness of 100 feet of gravel is exposed below the lava, and a few acres has been washed off along the edge. At Yankee Jim there is a larger area of gravel, from 40 to 100 feet thick, which toward the east disappears under the lava. The gravel is fairly coarse, being composed of metamorphic rocks, with some quartz. The bedrock elevation, 2,595 feet, is about the same as at Georgia Hill, and the main channel seems to have had a northeast-southwest direction, though a somewhat higher channel extended eastward and probably connected with the Smiths Point bench gravel 1½ miles distant, on the South Fork of Brushy Creek. The gravel at Smiths Point is 50 feet thick, interstratified with sand. It is estimated that 8,630,000 cubic yards have been removed from Georgia Hill, Yankee Jim, and Smiths Point, and that yield has been about $5,000,000. The amount remaining available for hydraulic work is undoubtedly less than that removed, for the volcanic cap would soon make hydraulic work impossible. A quarter of a mile east of Georgia Hill the Anthony Clark tunnel has recently been run in a southerly direction for 550 feet, and is reported to have shown the existence of a large channel with much granitic detritus. The tunnel was found to be too high, striking the channel above bedrock.

It is believed that the Yankee Jim channel extended northward toward Wisconsin Hill via Kings Hill. It is also believed that it connects, below the lava, with the Dardanelles channel, though the later intervolcanic channels may have removed much of the earlier accumulations and in some places destroyed the older channel.

DARDANELLES, MAYFLOWER, AND BATH.

At Dardanelles and Forest Hill the canyon slope has exposed, below the lava, a long, low trough filled with gravel and rhyolitic tuff (Pls. V, p. 30; XXIV, *A*). The gravel is moderately coarse, is composed of quartz and metamorphic rocks, and is well cemented near the bedrock. Above it rests rhyolitic tuff intercalated with some gravel, clay, and sand. The thickness of these two formations varies exceedingly. At the New Jersey claim the gravel is only 8 feet thick and is overlain by rhyolitic tuff. At Dardanelles it has a maximum thickness of 70 feet. In the region about Mayflower are extensive bodies of rhyolitic tuffs, with intercalated gravels, as well as clays and sands of more doubtful origin. The depth of these accumulations at Mayflower, over the deep channel, is 350 feet. In the intercalated gravels granitic and rhyolitic cobbles are common. At the Adams tunnel 178 feet of rhyolitic clays are exposed, with two smaller gravel bodies. At the Blackhawk, Wasson, and Westchester claims similar bodies are exposed. At Bath the same channel is exposed with about 250 feet of overlying gravels and white tuffs. The lower part is a trough 500 feet wide and 100 feet deep, filled in the bottom with washed and rounded bedrock bowlders, composed chiefly of serpentine and greenstone. Above this comes a thick stratum of the usual coarse quartz gravel, and above this a series of rhyolitic tuffs with intercalated gravels, which have a maximum thickness of 30 feet and contain granite and rhyolite bowlders. The rhyolitic series varies from 100 to 250 feet in depth, and it is in turn covered by 270 to 300 feet of andesitic tuff-breccia.

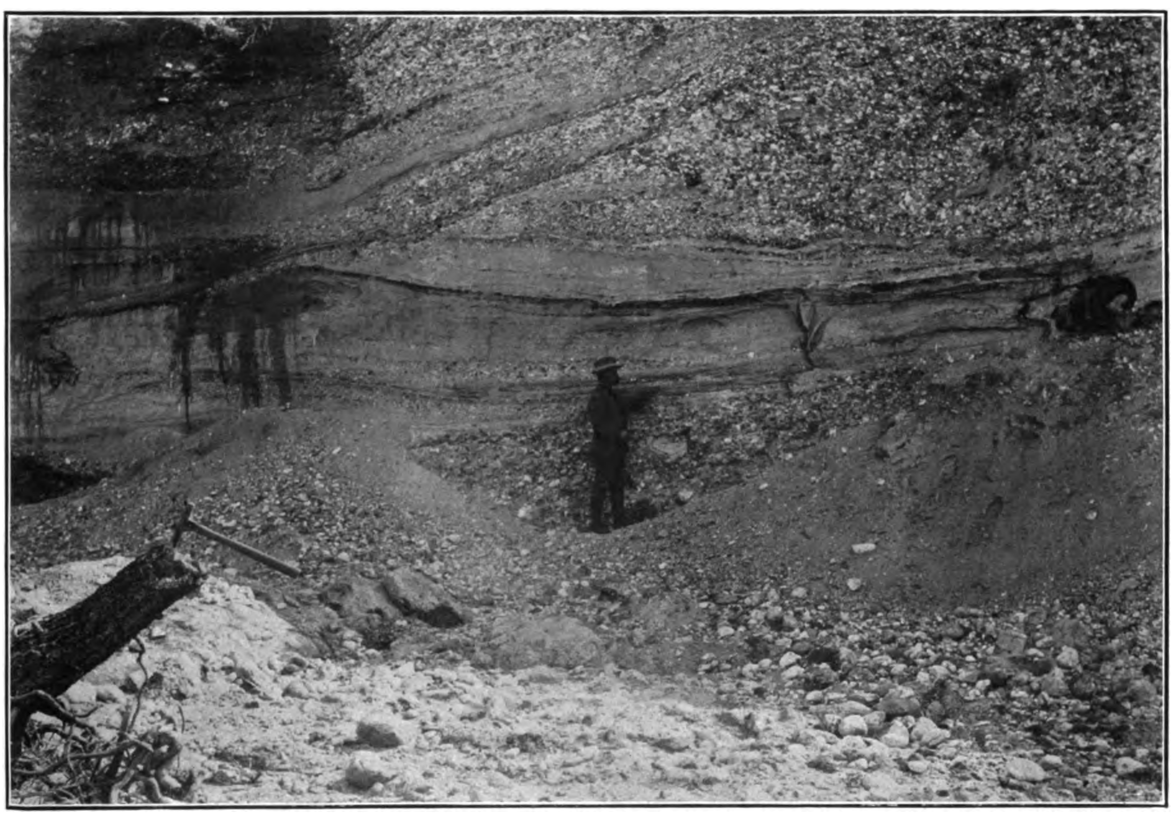
The main prevolcanic channel enters the ridge at Bath (bedrock elevation 2,900 feet) and runs northward for a mile with very slight grade, then curves west and south, assumes a grade of 60 feet to the mile, and passes below Mayflower (bedrock elevation 2,800 feet) and Forest Hill to Dardanelles (bedrock elevation 2,670 feet), where it curves northwest again toward Yankee Jim without leaving the ridge.

The mining operations in this vicinity have been very extensive. (See Pl. XXV.) Hydraulic work has mainly ceased, though a considerable amount of ground is still available at Dardanelles and around the head of Brushy Canyon. At Dardanelles (Pl. V, *B*, p. 30) and at Forest Hill 4,850,000 cubic yards has been excavated; at the head of Brushy Canyon probably 7,350,000 cubic yards.

The main old channel has been drifted at Dardanelles for 2,500 feet in a northwesterly direction, to a point where it was cut out by a deeper, intervolcanic channel. The gravel,

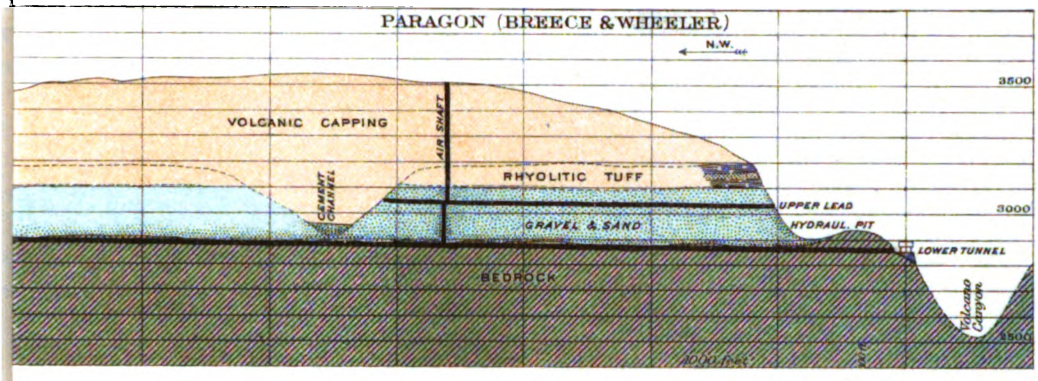
A. RHYOLITIC TUFF RESTING ON BEDROCK OF DARDANELLES CHANNEL, FOREST HILL, PLACER COUNTY.

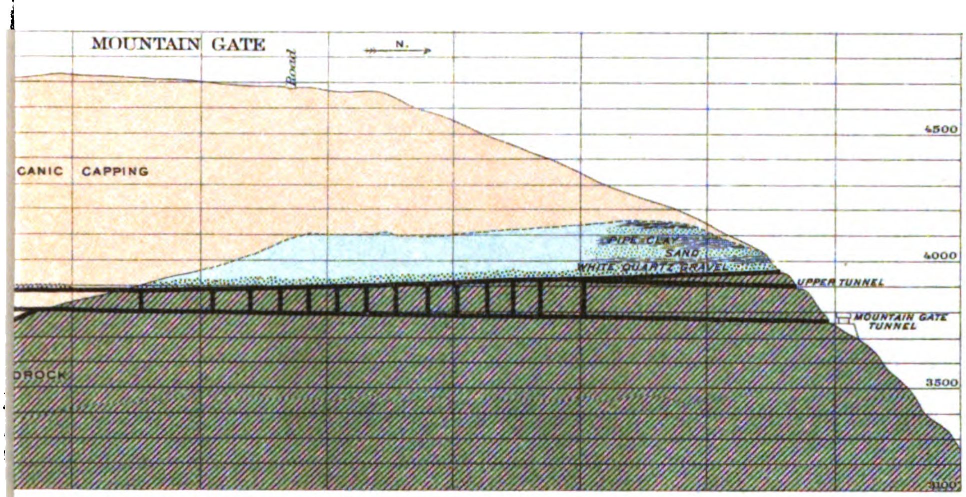
In the background is seen a later channel filled with andesitic tuff in a trough eroded in rhyolite. The same channel is shown in the background of Plate V, *A* (p.). Photograph by J. M. Boutwell. See page 150.



B. UPPER BENCH GRAVEL AT MOODY MINE, GOLD RUN, PLACER COUNTY.

Showing cross-bedding. Photograph by Waldemar Lindgren. See page 145.





ALIFORNIA

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which is cemented, was 5 feet deep and 75 feet wide. Mining was still progressing here in 1901. The mine is believed to have produced $2,000,000 or more by drifting and hydraulicking.

Below Forest Hill a number of smaller depressions called "front channels" were worked many years ago from the Jenny Lind and New Jersey tunnels. The main channel has been reached by the Baltimore tunnel and Excelsior slope, but some drifting ground still remains between these points and the Mayflower. The ground in this vicinity is supposed to have produced $5,000,000, about $1,500,000 being taken from a strip of ground in the New Jersey claim 800 feet long and 300 feet wide. These channels undoubtedly belong to the intervolcanic epoch.

From the Mayflower tunnel, 4,740 feet long, the main channel has been worked, chiefly from 1888 to 1894, for a distance of 3 miles, connecting it with the Paragon workings. (See Pl. XXV.) A bed of gravel from 2 to 14 feet thick, having an average width of 75 feet, was removed from the bedrock. The yield has been approximately $1,500,000, or $7 to the ton of loose gravel delivered. Two-thirds of the bottom gravel was found to pay for extraction.

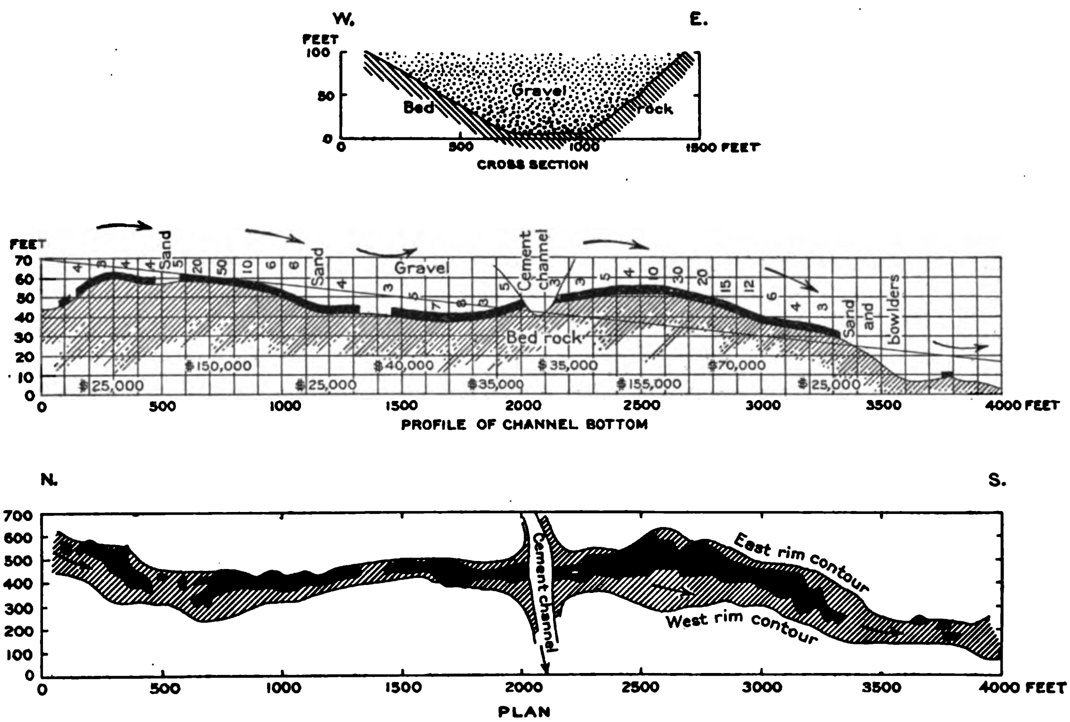


FIGURE 12.—Section, profile, and plan of part of Mayflower channel, Forest Hill divide, Placer County. (After Ross E. Browne.) Black areas indicate pay gravel. In the profile the amounts at the bottom indicate the gold extracted from the different sections, and the figures above the black areas show the average value per ton of gravel, ranging from $3 to $50 at intervals of 100 feet.

(See fig. 12.) Between the Paragon and the Mayflower, in the bend, is a narrow gorge 1,000 feet long, where the channel is only 25 feet wide and poor in gold. An "upper lead" or streak of gravel inclosed in the rhyolitic tuff, 150 feet above the bedrock, and paying for drifting, is said to exist along the Mayflower channel as well as at the Paragon at Bath, but it has not yet been worked to any extent. Little work is being done at present on the main channel at the Mayflower.

The same channel has been worked from the Paragon mine to a distance of 6,800 feet north. The width of gravel breasted is 50 feet, the depth 2 to 7 feet, the yield per ton delivered at the surface $10, and the total yield by hydraulicking $500,000 and by drifting $850,000. At the Paragon there exists an upper streak of pay gravel 150 feet above the bedrock; this was followed for 2,000 feet until cut off by a channel of intervolcanic erosion filled with andesitic tuff. The width of this upper lead was 225 feet, the depth of noncemented pay gravel 5 feet, and the yield per ton of loose gravel $4.50. The total yield was $900,000. The mine has been operated for 36 years, and the channels are said to be nearly worked out.

MICHIGAN BLUFF AND BYRDS VALLEY.

A portion of what is doubtless the same channel has been preserved at Michigan Bluff, where the bedrock elevation is 2,320 feet. The deposit, which covers about 40 acres, is composed of pure quartz gravel; on the bedrock lie huge rounded quartz bowlders. Some 6,000,000 cubic yards has been removed and a smaller quantity remains. The yield is reported to have been $5,000,000, some of the ground being exceedingly rich. The deposit bears the character of bench gravel. At Sage Hill and Byrds Valley a long, narrow channel, with strong southwest grade, is preserved; its outlet at Sage Hill is somewhat lower than Michigan Bluff. It has been worked to some extent, but is not so rich as that at Michigan Bluff. Much coarse, rough, and crystallized gold was found here as well as in Mad and Lady canyons.

HIDDEN TREASURE WHITE CHANNEL.

At Edwards Hill a small patch of partly volcanic gravel has been worked. From this point north a number of small gravel points appear along the brink of Eldorado Canyon, most of which belong to intervolcanic channels. At Gas Hill, however, there is a patch of the same quartz gravel as is exposed at Michigan Bluff. Immediately to the north it is eroded by deeper volcanic channels, but between Hidden Treasure and Damascus a nearly continuous prevolcanic channel, having a southward grade of 70 feet to the mile, has been found under the lava cap. This is a wide, flat channel, with fairly soft clay slates as bedrock, and it is filled about 200 feet deep with uncemented quartz gravel, sand, and clay. The material is decidedly finer than that of the Bath-Mayflower channel, though some quartz bowlders may be found on the bedrock. It is cut off by two deeper intervolcanic channels, one a mile south of Damascus, another 1½ miles north of Sunny South; between these a fragment of the old "white" channel remains. This channel has been worked for 30 years. It was first found at Damascus, where the bedrock elevation is 3,944 feet, and was drifted on to the point where it is cut off by the intervolcanic channel mentioned. The yield of this part is reported to be $6,000,000. From Sunny South, 3½ miles farther south, where the bedrock elevation is 3,644 feet, the Hidden Treasure Co. has worked the deposit for 7,700 feet northward. The width of gravel breasted was 250 feet; the depth 4 to 7 feet, including 1 foot of bedrock; the yield of loose gravel delivered from 50 cents to $1.75 a ton. The working costs, which are unusually low, approximate 50 cents a ton. The gold is coarse and well washed. Nuggets of a value of 10, 25, and 50 cents are fairly common. The total yield to 1890 was $1,150,000, and up to 1898 probably nearly $2,000,000.[1] Since that time the operations at Sunny South have been discontinued. Another tunnel has been started at the Dam claim, 1 mile farther north, and proved that only a small strip of the white channel was cut through by the later intervolcanic channel. The gravel of Hidden Treasure was found again beyond it, and has been successfully mined up to the present time (1907). In places the channel widens to 800 feet, with rims rising very gradually to a height of 16 feet above the lowest depression. At the same time it swings somewhat northwestward, and thus the original estimate of the probable amount has been greatly increased. Plate XXV gives a longitudinal section of the workings according to Ross E. Browne's map, in the Tenth Report of the State Mineralogist.

LONG CANYON.

The broad ridge between the Middle Fork of American River and Long Canyon, partly in the Placerville quadrangle, is covered by very heavy accumulations of gravel, rhyolite, and andesite. North and south of this ridge the bedrock rises steeply, and the configuration of the ridge shows that below it is a deep trough representing a very important Neocene river course. There is no doubt whatever that this channel forms the eastward continuation of that which enters the ridge at Bath and which once ran a little south of Michigan Bluff. The bedrock relations alone are sufficient to prove this, but besides there exists a most striking similarity between the deposits at Bath and those on the Long Canyon divide. The outlet of this channel is located at the Ralston diggings (Pat Goggin's mine), where the bedrock elevation is 3,475 feet. From this point the channel makes a curve and lies in the Placerville quadrangle for a

[1] The total production of the mine up to 1910 is about $3,500,000.

short distance. Again entering the Colfax quadrangle, it must continue below the volcanic masses in a northeasterly direction. Its identity with the channel of French Meadows and Soda Springs (in the Truckee quadrangle) is indicated beyond all doubt. At no place between Ralston's and Soda Springs, however, is the bottom of the channel exposed. There appears to be but little prevolcanic gravel on the Long Canyon divide. Most of the gravel is interstratified with rhyolitic tuffs, forming a series 160 feet thick at Ralston's and at least 250 feet thick at Blacksmith Flat, 4 miles to the east on the southern slope of the ridge, where the bedrock elevation is 3,800 feet. Hydraulic operations have been carried on successfully to some extent at Ralston's and at Blacksmith Flat. The gravel everywhere contains granite bowlders, indicating that the stream came from the higher part of the Sierra Nevada. At many places along the south rim in Long Canyon, northeast of Blacksmith Flat, small mining operations have been carried on. At Russian Ravine the surface gravel was hydraulicked with excellent results. In addition to those at Ralston's, small operations have been carried on in Brushy Creek, at the north side of the ridge, and also at a point 1½ miles north of Russian Ravine. At the latter place, at an elevation of about 4,500 feet, it is believed that an inlet exists near the point where the tributary from Duncan Peak entered the Long Canyon channel. The gravel at this place is 150 feet thick and contains large bowlders of quartz and metamorphic rock. It is covered by heavy masses of rhyolitic tuff. The gold in the gravels embedded in the rhyolitic series is generally fine.

Extensive prospecting operations of recent date show that the main channel on the Long Canyon divide is broad and flat and that the gravels cover large areas but are generally of low grade. Intervolcanic channels do not seem to exist. Hydraulic operations were in progress in 1891 at Ralston's (Pat Goggin's mine) and at Lynchburg, about 3 miles to the southeast, on the southern slope of the ridge.

CONNECTIONS OF THE CHANNEL SYSTEMS.

The general Neocene drainage system of this quadrangle has been roughly considered (pp. 134–135), but it remains to indicate in a more detailed way the connections of the channels of the southern part of the area with those of the region between Dutch Flat and North Columbia.

A river corresponding roughly to the present Middle Fork of the American had its source near Castle Peak, in the Truckee quadrangle, thence flowed across to Soda Springs and approximately followed the course of the present Middle Fork, entering this quadrangle along the line of the present ridge between Long Canyon and the Middle Fork and at the southern portion of this ridge curving into the Placerville quadrangle. It reentered the Colfax quadrangle a few miles farther west, and the channel emerges from under the volcanic capping at Ralston's. A tributary from the Duncan Peak region joined it with a general southerly direction. From Ralston's much of the channel is eroded, but it may be regarded as certain that the main channel continued westward, touching Michigan Bluff and Sage Hill and here receiving an important tributary running nearly due south from Damascus. The deposits of this tributary channel are preserved below the lava ridge between Damascus and Gas Hill. Near Gas Hill it received a tributary from Last Chance and Deadwood.

East of Michigan Bluff the channel is eroded, but its continuation is found at Bath, whence the main channel ran through to Mayflower. Here it made a wide curve and ran southward to Forest Hill and Dardanelles. Thus far the general course is outlined without uncertainty, but from this point on the difficulties begin. The main channel is broad and well defined and is marked by its heavy deposits of gravel and clay. Under the southwestern prolongation of the Forest Hill lava ridge nothing has thus far been found which would indicate that the main old river flowed down in this direction. It is true that a narrow channel of the intervolcanic epoch extends down in this direction, but the intervolcanic channels were notably independent of the older and main drainage basins, being excavated after a large part of the old river basins had been filled by accumulations of silt and volcanic mud, and probably also after the tilting of the Sierra Nevada had taken place. Their direction thus affords no criterion of the prevolcanic drainage lines. It would certainly seem as if some fragments of the accumulations of the old

channels would have been preserved southwest of Dardanelles had the channel taken this course. The gravels exposed at Todd Valley offer no solution of the problem, for they are at a higher level and evidently represent a bench filled with gravel after the clogging of the main channel.

The following solution of this problem is advanced as being most plausible: It is believed that the old channel of the Forest Hill divide emerges at Yankee Jim and Georgia Hill and trends northward to Wisconsin Hill, thence through the lava ridge and curving eastward to the Morning Star mine, thence to Iowa Hill, crossing the canyon of the present North Fork of American River to Indiana Hill, and thence northward to Dutch Flat, beyond which its course has already been established. This hypothesis in the first place necessitates the existence of a deep and continuous channel between Dutch Flat and Indiana Hill. That such a deep channel exists appears now very probable and may be regarded as certain if the developments south of Dutch Flat show the existence of a deep trough at this place, which it has been asserted was found by the explorations. One of the principal difficulties appears to be the fact that the gravel at Georgia Hill and Yankee Jim differs somewhat in character from that of the Mayflower mine and Forest Hill. This may be explained by the fact that the river near Yankee Jim spread over a larger and flatter bottom, which would naturally influence the character of its deposit.

The difficulty which at first glance appears to be insurmountable—that of the grades—on closer examination converts itself into an argument in favor of this hypothesis. From Dardanelles to Yankee Jim is a slight grade which is sufficient for the requirements. From Yankee Jim to Wisconsin Hill the channel would at present have a slight upward grade. From Wisconsin Hill to Iowa Hill it is apparently approximately level. From Iowa Hill to Indiana Hill it has a slight southward grade, and similarly from Indiana Hill to Dutch Flat is a grade which, though slight, is opposite to that which the river, according to this hypothesis, would have had.

From Yankee Jim to Dutch Flat the Neocene river would have pursued a nearly due northerly course. Now it is likely that this river from Yankee Jim to Dutch Flat had originally a very slight grade northward, similar to that of the Neocene river between You Bet and North Columbia. Examinations of channels in other parts of the Sierra Nevada have shown the occurrence of a tilting movement which has affected the grades of the channels according to their direction. Channels running from north-northwest to south-southeast, or the reverse, have retained their original slight grade. Those running in a more westerly direction have had their grades materially increased by the tilting. On the other hand, those flowing in a more easterly direction from this axis of tilting have had their grade decreased or even reversed. A close examination of the elevations of Indiana Hill, Dutch Flat, Iowa Hill, Wisconsin Hill, and Yankee Jim will show that in fact the present levelness or slight southward grade of the channel is exactly what would have resulted if the Neocene river, with a northerly course, had participated in a westward tilting of the block of the Sierra Nevada amounting to about 60 or 70 feet to the mile.

If this hypothesis is true it solves, in an exceedingly satisfactory way, a number of the perplexing problems which were presented by the enormous accumulation of gravels in the drainage of the old Yuba River. It increases vastly the drainage area of the Neocene stream, which, as now outlined, extends from the headwaters of the North Fork of the Yuba. The waters of all this territory found an outlet through the narrow channel from North San Juan to Smartsville. In the central part of this drainage area longitudinal depressions existed, bordered on the west by the high diabase ridges of the foothills. All these conditions naturally tended greatly to increase the accumulation of gravels. What has formerly been supposed to be the North Fork of the Neocene American River now becomes the South Fork of the great Neocene Yuba River. The Neocene American River is reduced in size and consists only of the stream coming down from Pyramid Peak by way of Placerville.

INTERVOLCANIC CHANNELS.

FOREST HILL DIVIDE.

During a rather long interval between rhyolitic and andesitic flows new channel courses were established. A disturbance had taken place that increased the slope of the Sierra Nevada, and the streams began active cutting. Thus on the Forest Hill divide there exists a complicated system of narrow, deep channels, which in many places have destroyed the old ones. These intervolcanic channels, often called cement channels, belong to at least two systems. The younger channels are characterized by a large amount of coarse volcanic gravel, rarely containing much gold, and were formed after the first andesitic flows had already invaded this region. The older channels carry thin, mixed metamorphic and volcanic gravel, rarely more than 10 feet thick, there being no gravel at all along certain parts of the streams. This gravel lies on the bedrock and is covered by a series of flows of andesitic tuff, the lowest usually fine grained and referred to as "chocolate" or "cement;" the upper flows consist of the usual tuffaceous breccia. Strata of gravel and sand of mixed character, volcanic and metamorphic, are found in many places interbedded with the andesitic tuff. Wherever the intervolcanic channels have robbed the old channels they are likely to be rich, though of irregular value. Some of them, however, have been found unexpectedly poor. The gold they contain is usually coarse. Locally the upper gravels in the andesitic tuff carry gold, though as a rule not enough to pay for drifting. Some of the volcanic channels have not only cut through the old channels but have eroded small canyons in the bedrock up to a depth of 150 feet. One of the most conspicuous of these crosses Volcano Canyon and is exposed by the Hazard shaft. The grade of these channels is always steep, usually from 70 feet to the mile upward.

A whole channel system belonging to this period is buried below the lava of the Forest Hill divide. The principal channel can be traced almost continuously from the Weske tunnel, above Michigan Bluff, down to the outlet at Peckham Hill. It cuts the old channels at several places and receives numerous tributaries, preserving throughout the same character of a deep erosional channel, here barely reaching the bedrock, there cutting deeply into it. At Peckham Hill and the Blue Gravel shaft (214 feet deep), in the Placerville quadrangle, it has been opened but apparently does not pay. For 2½ miles north of Peckham Hill its bottom has not been exposed, but it has been opened by the Gray Eagle tunnel from Owl Creek, 2,500 feet long, and by a shaft 360 feet deep. The elevation of the tunnel portal is 2,300 feet. Though somewhat too high the tunnel has followed the channel upstream for several thousand feet. The pay is spotted, the gravel thin, though in places rich. A mile to the northeast from the Gray Eagle it has been opened by the Centennial slope, where the bedrock of the channel lies at 2,461 feet.

The Dardanelles channel was cut off about 2,400 feet north from its inlet by the main intervolcanic channel, which here is 100 feet lower than the prevolcanic channel and has been worked upstream for about 300 feet.

In the Mayflower mine the intervolcanic channel is again exposed; it is here called the Orono and has cut down to about the level of the bedrock in the Mayflower channel. (See fig. 12, p. 151; Pl. XXV, p. 150.) From this point it has recently been worked for a distance of 2,000 feet through the Mayflower tunnel. Again, a little below the month of the Mayflower tunnel a channel called the Live Oak crosses Brushy Canyon at a lower elevation than the Mayflower. This has been drifted on northward for 2,000 feet; to the south it probably joins the Orono channel. Below the volcanic capping between the forks of Brushy Canyon are several smaller intervolcanic channels, such as the Adams, Nil Desperandum, Westchester, Blackhawk, and Wassen; the relations of these are little known.

Farther east the main channel is again found in the Paragon mine, where it has not quite cut down to the bottom of the old channel. It is exposed also where it crosses Volcano Canyon, in which the Hazard shaft has been sunk 180 feet. The bedrock elevation of the channel is here 3,156 feet. The narrow channel was followed westward for 3,000 feet and some rich gravel was found. Above the channel has not been exposed for about 2 miles, though a deep tunnel

from a point near Michigan Bluff has been proposed. But above this stretch it has been drifted for over 5,000 feet in a westerly direction from the Weske tunnel, the portal of which has an elevation of 3,356 feet. The channel itself is being drifted downstream and stopes and pumps were necessary. The bedrock elevation half a mile from the portal, in the tunnel, is about 3,300 feet. In spite of difficult working conditions this enterprise yielded excellent returns, producing approximately $750,000. The Weske channel is at most 100 feet wide, and in it compact andesite tuff overlies the thin gravel. The bedrock is smooth and hard. The grade is steep, with many sharp descents and potholes. Several tree trunks were found standing upright in the tuff.

A smaller intervolcanic channel, filled with heavy volcanic gravel, crosses the Weske channel near its inlet and thence continues some distance north. It has not been worked to any extent. About a mile north of the Weske channel a small old stream bed has been worked to some extent from the Bowen and Oro tunnels. The Oro is about 2,500 feet long.

Above the Weske tunnel, confronting Eldorado Canyon, there are a number of smaller gravel hills, most of which have been hydraulicked. Among these are Drummonds Point, Eldorado Hill, and Bachelor Hill. The gravel at all these places appears to belong to the intervolcanic epoch, and the deposits evidently form part of a somewhat complicated channel system, near the point where the channels from Deadwood join those coming down from the main ridge. It is probable that the channel on which the Oro tunnel is driven finds its way down below the level ridge on the west side of the Hidden Treasure tunnel, but it has not been exposed north of the Oro tunnel.

A narrow intervolcanic channel, carrying heavy volcanic gravel and apparently barren, runs north for some distance from Sunny South, parallel but a little east of the Hidden Treasure channel. At Sunny South it has cut across the Hidden Treasure channel, obliterating it and eroding some distance into the bedrock below. This is the reason why no quartz gravel can be seen cropping out at Sunny South. About a mile south of Damascus the Mountain Gate channel (see Pl. XXV, p. 150) was cut off by a deeper intervolcanic watercourse, eroded to a depth of about 150 feet below the older channel. This so-called blue channel was drifted from the Mountain Gate tunnel, producing $175,000. A little over 2 miles north of Sunny South the same old channel is cut to 30 feet below the bedrock by another intervolcanic channel.

The Dam channel, though narrow and irregular, has been drifted for 2,500 feet northwest of the point where it crosses Eldorado Canyon. The Mitchell claim, on the same channel, has also been worked for a distance of 2,000 feet. Still another intervolcanic channel, called the Bob Lewis channel, has been worked for a thousand feet south of its inlet on the east side of the Mountain Gate channel at Damascus. The principal intervolcanic channel, which probably continued from the Oro to the blue channel of the Mountain Gate tunnel, has also been exposed at Red Point.

RED POINT MINE.

The Red Point mine is situated on the slope toward the North Fork of American River, 1 mile east of Damascus. The elevation of its tunnel at the portal is 3,875 feet, or 2,000 feet above the river. An excellent description of this enterprise has been furnished by its superintendent, Charles F. Hoffmann.[1]

The deposit is a narrow intervolcanic channel, first found in the Golden Gate mine, near Damascus, and continuing eastward underneath the cap of andesitic tuff for a distance of about 8 miles. The channel carries pay gravel only in a part of this distance.

The Red Point channel has cut through the older "white" channel of Mountain Gate to a depth of 90 feet below its bedrock. The later channel was worked through a winze for a distance of 1,400 feet upstream and downstream, and its course was established as nearly at right angles to the white channel. The Red Point tunnel is 1,840 feet long, and from the place where the upraise struck the wash the channel has been worked by the Gold River Mining Co. (a French corporation) for 500 feet downstream to the west and for 12,000 feet upstream.

[1] The Red Point drift gravel mine: Trans. Tech. Soc. Pacific Coast, vol. 10, No. 12, January, 1904.

The production from January 1, 1884, to December 31, 1892, was 140,345 carloads of 22 cubic feet each, yielding $308,245, or $2.20 a carload. A distance of 5,073 feet yielded at the rate of $71.65 a running foot. The total expense per carload was $1.64. The production of the mine from 1893 to 1903, when it was closed, was about $700,000.

The channel occupies a typical river bed, with all its windings, bars, potholes, etc.; several islands have been encountered, rising 12 or 14 feet above the bed. Three large potholes were 80 to 120 feet long, 50 feet wide, and 9 to 14 feet deep. The bottom width of the channel is from 75 to 650 feet, averaging 200 feet. The grade is about 70 feet to the mile. From a point near the tunnel where the elevation of the bedrock is 3,860 feet the elevations increased along the channel to 4,065 feet 2¾ miles to the east-northeast. The potholes were found in hard rock. The soft rock is more uniformly graded and has a level surface. The bedrock is a clay slate, with some calcareous schists and sheets of diabase and diorite; quartz veins were also found, but proved unprofitable. The gravel consists of bowlders of metamorphic rocks and porphyries, with but little quartz; it is not cemented, but rather soft and of grayish color when dry. The depth ranges from a few inches on the rim to 7 or 8 feet in the center of the channel. Hard andesitic tuff with volcanic bowlders immediately overlies it. Much of the gravel is coated with minute quartz crystals. The coarse gold constitutes 16 per cent, medium-size gold 48 per cent, fine gold 36 per cent, and "powder" (passing through 40-mesh screen) 0.32 per cent. The fineness averages 933. The distribution of the gold is irregular, but most of it is found on the bedrock, though in some sections it is mostly in the gravel above. The richest spot in this mine was found in a layer of gravel 6 to 12 inches above bedrock. Gold is also found in paying quantities in an upper layer 10 to 40 feet above bedrock. The gold dust lodges in small pockets or cracks in the bedrock to a depth of 1 foot or more. The lowest rut in the channel contains very little gold; the bulk of it is thrown on the sides or on higher rock.

EUREKA TUNNEL.

About a mile northeast of the Dam tunnel of the Hidden Treasure Co. is the Eureka tunnel, which some years ago was driven about due west for 4,223 feet, with the expectation of striking an intervolcanic channel. The elevation of its portal is 3,820 feet. At a distance of 4,223 feet from the portal heavy andesitic wash was entered. The gravel of this volcanic channel was poor in gold.

HOGSBACK AND CANADA HILL.

Toward the higher region of the Sierra, where accumulations of prevolcanic gravel were small or did not exist at all, the difficulty of distinguishing between prevolcanic and intervolcanic channels becomes greater. Strictly speaking, all the channels in this higher region must be considered as belonging to the latter group, as some erosion necessarily took place in all of them in which bedrock was exposed. In going up toward Duncan Peak we find in general that the grades of the channels increase and that they assume more and more the character of narrow tributaries or gulches.

It is believed that the Red Point channel continues up the ridge. It has indeed been exposed at the Hogsback tunnel, 5½ miles northeast of Red Point, the elevation of the portal being 4,324 feet. The tunnel runs south-southwest for 2,500 feet, exposing a very deep and narrow gorge, with steep westerly grade, and contains very little gravel. The bedrock elevation is about 4,500 feet. Though yielding some gold the channel was not found to pay. The inlet of the Hogsback channel is probably found at the low place half a mile north of Secret Canyon House. About a mile south of the Hogsback channel another deep Tertiary ravine has been exposed at the Greek mine and at Black Canyon, between which it is probably continuous. The Black Canyon channel has been worked for 700 feet eastward; it is narrow and very steep, having a grade of 7 feet in 100 feet, with several abrupt falls. The bedrock elevation is 4,768 feet near the shaft. On the bedrock rests a few feet of coarse gravel, containing very coarse gold. Above this lies 50 feet of andesitic tuff, gravel, and sand interstratified. No volcanic pebbles were seen in the gravel and the channel probably belongs to the prevolcanic period. The cost of working is necessarily very high. Near Canada Hill another steep, narrow

channel has been exposed, which appears to have a very sharp northeasterly grade. This channel probably crosses Sailor Canyon, entering the Truckee quadrangle, and then joins the main channel, which approximately follows the Middle Fork of American River near French Meadows. The west end of the Canada Hill channel is not covered by volcanic rocks but by heavy morainal detritus. A short distance eastward the volcanic rocks begin, and at the Reed mine, half a mile east of its west end, they cover it to a depth of about 100 feet. A few feet of poorly washed gravel is found in the bottom of the channel, above which is a few feet of clay containing carbonized wood. Above this lies a little massive rhyolite covered by heavy masses of andesitic breccia. This channel has been successfully drifted and in places hydraulicked as far as the point where it enters the high volcanic ridge. It is believed to continue with steep grade underneath this ridge, and its outlet has probably been found at the Sailor Canyon mine, 2 miles northeast of Canada Hill. At this place bedrock tunnels have shown the existence of a narrow channel containing angular, poorly washed gravel covered with a dark clay. The relations are somewhat obscured by considerable masses of morainal material.

DEADWOOD RIDGE.

Deadwood Ridge is crossed by channels belonging to both the earlier and later epochs, which have been worked for a long time but are not yet exhausted. The older channel enters the ridge on the east side near the Devils Basin at an elevation of 3,945 feet, while its outlet is located just west of Deadwood at an elevation of 3,706 feet, both figures being taken from a special survey made for J. O. Whitney, and connected with the work of Ross E. Browne on the Forest Hill divide. The distance is about 2 miles, giving a grade of 120 feet to the mile, the direction being west-southwest. This channel is characterized by thicker bodies of gravel containing chiefly quartz and metamorphic rocks, and has not been extensively worked.

A number of small intervolcanic channels exist, with as yet doubtful connections. In all of these the gravel is thin and directly covered by andesitic tuff. From the Devils Basin on the east side the Basin channel has been worked for about 1,000 feet westward. This is believed to be the same as the Elkhorn-Washington channel, which has been worked for several thousand feet eastward from the Washington tunnel, 4,000 feet north of Deadwood, the elevation at the end of the workings about the center of the ridge being 3,768 feet. About 4,000 feet south of this point the Rattlesnake intervolcanic channel has been worked through the ridge for a distance of 7,000 feet, from the Rattlesnake inlet on the east side (elevation, 3,765 feet) to the Hornby tunnel on the west side (elevation, 3,525 feet). The intervolcanic channels are about 150 feet deeper than the prevolcanic stream bed.

LAST CHANCE.

At Last Chance several channels are known to occur and have been drifted for considerable distances, although leaving some ground as yet unopened. As at Deadwood, there is a prevolcanic channel and several intervolcanic channels. Both classes follow approximately the same course, though the intervolcanic channels are about 24 feet lower than the others. The gravel and its covering material are similar in character to those at Deadwood. The upper continuation of the Last Chance channels may probably be found at American Hill, on the ridge between Lost and Antone canyons. The outlet lies at an elevation of about 4,200 feet opposite Devils Basin, and the inlet of the channel is at Startown, about 2 miles to the east-northeast, at an elevation of about 4,400 feet.

DUNCAN PEAK.

Below the volcanic areas south of Duncan Peak narrow and deep channels have been found, which, however, have not yielded much thus far. One of these extends from Flat Ravine, where the bedrock elevation is 6,000 feet, southward for 1½ miles It has been opened by tunnels at both ends and worked to some extent. Another channel is exposed by the Abrams tunnel, on the west side of Duncan Canyon. This branch probably joins that from

Flat Ravine and, crossing under the lava ridge between Duncan Canyon and the Middle Fork of American River, becomes a tributary of the main Long Canyon channel. The andesitic tuff lies almost on the bedrock. There is very little gravel in these Neocene gulches. Depressions indicating channels also exist below the andesite areas of Big Oak Flat.

QUATERNARY GRAVELS.

The Neocene gravels derived their rich contents of gold from the disintegration of quartz veins. The Pleistocene gravels, still richer, though of less extent, derived their gold not only from the continued disintegration of the quartz veins but also from that stored up in the older Neocene channels as they were gradually destroyed during the process of erosion. As is well known, the Pleistocene gravels were the first to be mined after the discovery of gold in California. The miners followed up each stream, and wherever prospects appeared to be good washed the low bars with water easily obtained from the river. A little later the higher benches, up to 100 feet above the river, were attacked. In the same manner each stream was followed up, in case it proved to be valuable, and its gravels, wherever occurring, were washed.

All these Quaternary gravels are now practically exhausted, and some have been washed over two or three times. A few Chinese are still washing the bars of the Middle Fork and South Fork of the Yuba, either in a primitive way, by rockers, or by wing dams and sluices. Occasionally small patches of gravel not yet mined are found along the river sides.

Practically all the ravines in the western two-thirds of the quadrangle have been mined to a greater or less extent. The only barren region is that east of a line drawn from Graniteville to Emigrant Gap, and thence to Monumental Hill and the mouth of Big Valley. Even within this area gold placers have been found on upper Fall Creek, about a mile above the crossing of the road from Bowman Lake to Emigrant Gap. A little gold has also been washed near the summit of Grouse Ridge. The Quaternary gravels of Bear River, Greenhorn River, and Steep Hollow have been extensively washed but are now buried below tailings. (See Pl. XIII, p. 78.)

Along the North Fork of American River bars were numerous and rich as far up as Humbug Bar. At Green Valley, south of Towle, and at Hayden Hill mining operations have been successfully carried on until recently. Above this point the gravels were generally poor, though some have been washed as high up as Sailor Canyon.

The Middle Fork of American River was noted for its rich gravels, which extended up to a point south of Michigan Bluff. The vicinity of Gray Eagle Bar and American Bar was noted for its important gravel mines during the 10 years following the discovery of gold. Some work is even now carried on there. At one point the river makes a wide bend and a tunnel has recently been run with the expectation of draining this curve and mining the gravels exposed, which are believed not to have been reached by the old miners.

The North Fork of the Middle Fork contained gold up to its head near Canada Hill, while the main Middle Fork is reported to have been relatively poor, though not barren, from a point east of the Ralston mine. Dredging has recently been proposed as a means of working the remaining gravels, which have been covered by débris from the hydraulic mines, and plants of this kind have been projected for use on Bear and Greenhorn rivers. The hardness and unevenness of the bedrock is the principal obstacle. The small amount of gold in the tailings from hydraulic mines is gradually being concentrated by the rivers and much of this gravel will undoubtedly be worked over by dredging or some other process.

CHAPTER 13. THE TRUCKEE QUADRANGLE.

GENERAL GEOLOGY.

The Truckee quadrangle covers the first summit of the Sierra Nevada west of Lake Tahoe and parts of the great depression of Lake Tahoe and the Truckee Valley and of the second range between Lake Tahoe and the Nevada deserts.

The prevailing rock of the "Bedrock series" is granodiorite and allied intrusive masses. Along the western margin of the quadrangle lie slates and quartzites of Jurassic or Triassic age, with some old augite andesites (augite porphyrites) of the same period. These sedimentary masses are greatly disturbed and cut by the intrusive granitic rocks. The eastern range is mainly granitic, but only small exposures of the rock are contained in this area.

The whole of the Truckee Basin, the larger part of the eastern range, and almost all of the higher ridges on the western slope are covered by Neocene andesites. Rhyolites underlie the andesites on the western slopes.

GOLD-BEARING AREAS.

The quadrangle is very poor in gold-bearing deposits. The granitic rocks are almost entirely barren, as are the Tertiary lavas. Some gold-quartz veins are found near the western margin. At Meadow Lake auriferous veins with much pyrite and tourmaline are contained in granodiorite and augite porphyrite. There are some prospects on Snow Mountain and south of it in the augite porphyrite. The richest area of the "Bedrock series" lies near Sailor Canyon and constitutes the eastern part of the Duncan Peak and Canada Hill district, in the adjoining Colfax quadrangle. The total production is very small.

TERTIARY AURIFEROUS GRAVELS.

Auriferous gravels of Tertiary age are exposed only to a very minor extent in the Truckee quadrangle. Shallow gravel containing coarse gold has been found in the deep depression under the rhyolite near the head of Sailor Canyon, at the western boundary of the quadrangle. On the opposite side of Sailor Canyon, at the place called Sailor Meadows, similar deposits have been found. The gravels are developed by means of tunnels run into the bedrock.

At Chalk Bluffs, on the Middle Fork of American River, about 4 miles above French Meadows, an inclined shaft was sunk some years ago for a distance of 400 feet, with the intention of reaching the bottom of the gravel channel known to exist under the ridge north of the river. It is said that good prospects were found, although the bottom of the channel was not reached.

QUATERNARY AURIFEROUS GRAVELS.

As this region lies outside of the gold belt proper, Quaternary auriferous gravels of economic importance occur in only a few places, though by panning colors may be obtained from many creeks in the area. Sailor Canyon has yielded a considerable amount of gold, especially near its junction with American River, in the Colfax quadrangle. Some gold has also been found in the upper part of Duncan Canyon and in the Middle Fork of the American below French Meadows. The two branches of Long Canyon, which in the adjacent Colfax quadrangle are in places rich in gold, appear in this area nearly barren. The gravel bars along Rubicon River, from a point north of McKinstry Peak down, contain a small amount of fine gold.

TERTIARY TOPOGRAPHY.

The Tertiary surface of the Truckee quadrangle was of mountainous character. On the whole it sloped gradually westward from a summit line which practically coincided with the present water parting, and more steeply to the east of this divide down to a level of about 6,000

feet. Thence eastward the old slope is covered by andesite. The old divide has at present elevations of 7,000 to 8,000 feet. The Tertiary surface to the west of the divide appears to have been an irregular table-land, with a few flat-topped peaks rising above it. Among these, Snow Mountain and McKinstry Peak are the most prominent and are believed to form a part of the older, Cretaceous crest line of the range. In this table-land the watercourses had cut valleys which were broad and deep though not so sharply defined as the canyons of the present time.

A strongly marked depression began in the vicinity of Fordyce Dam and extended in a northwesterly direction. This contained the headwaters of Jura River, which, flowing northward, crossed the Downieville quadrangle, and the lower gravels of which are exposed near Mountain Meadows, north of Taylorville, in Plumas County. Another deep valley began a short distance south of Castle Peak and continued by Summit Valley and Onion Creek across to the present ridge between the North and Middle forks of the American, and thence down by French Meadows toward the head of Long Canyon. This canyon contained the headwaters of the Tertiary North Fork of American River. In a section from Snow Mountain (Pl. XVIII, *B*, p. 134) to Granite Chief the bedrock may be seen to rise within short distances 2,000 feet westward and 3,000 feet eastward above the old channel. A short tributary to this Neocene stream came from the vicinity of Sailor Canyon, flowing in an easterly direction, between the high hills of Duncan Peak and Snow Mountain. Another important tributary headed near Barker Pass and crossed Five Lakes Creek. Its abrupt character is apparent from the contact lines between the andesite and the bedrock. From Five Lakes Creek this channel was evidently followed by the volcanic flow down toward Grayhorse Valley to the head of Long Canyon. The flat summit of McKinstry Peak formed a prominent feature in the Tertiary landscape.

The eastern escarpment of the main range is well marked from Independence Lake southward, and the conclusion can not be avoided that it existed before the late Tertiary eruptions. Nothing definite is known of the configuration of the older rocks below the lavas of the Truckee Basin. Good reasons exist, however, for believing that they cover a deep valley which extended continuously from Lake Tahoe up to Sierra Valley.

The high and narrow Carson Range rises east of Lake Tahoe and continues northward, forming the eastern barrier of Truckee Valley. This range also existed in Tertiary time, though the part of it which falls within this quadrangle has been greatly increased in width and height by masses of lava poured out over its flanks. The old granitic core may be seen near Crystal Peak and has been exposed in Truckee Canyon by erosion of the volcanic flows. The contact lines of granite and lava show that a low gap with a present elevation of 6,500 feet existed in this range to the southeast of Crystal Peak. Again a part of the granitic core is shown near Hot Springs, on Lake Tahoe, the contact line against the lavas rising rapidly eastward.

FAULT LINES.

No evidence of important faulting is found on the western slope of the Sierra Nevada in this quadrangle. The eastern scarp, west of Lake Tahoe, on the other hand, is the result of an important fault along a line following its base; but no important dislocation has occurred along it since the lavas were poured out, and it probably antedates the Neocene period.

A similar fault line follows the western base of the Carson Range, although covering lavas mask its presence to great extent in this quadrangle. It is possible that in recent time slight movement may have occurred along this fault, as indicated by the position of certain Quaternary gravels at the base of the range.[1]

A third fault line follows the eastern base of the Carson Range and enters this quadrangle only in the extreme northeast corner. Along this line there have been several recurring movements. The first movement antedates the Neocene; the second dates from the Neocene volcanic epoch; the third and smallest dislocation has occurred during recent time. But these movements have not taken place equally along the line, and in this quadrangle no strong evidence appears of extensive postvolcanic faulting along the eastern base of the Carson Range.

[1] See Truckee folio (No. 39), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

CHAPTER 14. THE SACRAMENTO QUADRANGLE.

GENERAL GEOLOGY.

The southwestern part of the Sacramento quadrangle is occupied by the Quaternary gravels and alluvium of the Great Valley. The bedrock formations of the northeastern half include the central granodiorite area of Rocklin, which is on the east side bordered almost entirely by amphibolitic schists. A strip of Mariposa formation (Jurassic) is embedded in the amphibolites of the southern part of the quadrangle, and an irregular area of clay slates and limestones of the Calaveras formation (Carboniferous) is contained in the amphibolites of the northeast corner. Of the superjacent series light-colored clays and sandstones of the Ione formation (Miocene) overlap the first foothills of older rocks to an elevation of 400 or 500 feet; in the Chico quadrangle, farther north, the same formation attains an elevation of 1,000 feet. The central part of the quadrangle was probably covered by andesitic tuff at the end of the Pliocene epoch. The principal flow coming down from the region of Auburn and Colfax probably occupied the whole of the central depression produced by the easily eroding qualities of the granite. It spread southward to a point about 6 miles south of Folsom, and northward at least as far as Lincoln. A few small exposures of the Chico formation (Cretaceous) are known in this area, near Folsom. The highest elevation attained is 300 feet.

No faults have been observed in the "Bedrock series."

GOLD-BEARING AREAS AND PRODUCTION.

The gold-bearing area is restricted chiefly to the northeastern half of the quadrangle. The principal quartz veins are found all along the periphery of the Rocklin granitic area, either in the granodiorite or in the amphibolite. The most valuable deposits occur near Auburn and Ophir; the surface placers in the district have yielded millions of dollars, and the production of the quartz veins is estimated at about $3,000,000. South and north of Auburn the amphibolites contain many small veins which have furnished material for the shallow placers. The vicinity of Clarksville, Eldorado County, is rich in pocket veins.

The present American River, particularly the North and Middle forks, proved to be rich sluice boxes containing, besides the local gold, much fine gold carried down from upper Placer County. Its bars have also been rich throughout and the Quaternary gravels, spreading out at the mouth of the canyon at Folsom, have yielded many million dollars and are worked up to the present day. Extensive operations by several dredging companies have lately increased the yield.

The production from quartz mines is now small, and most of the output is obtained along the contact belt of granodiorite and schist, from the Zantgraff mine to the Three Stars mine. The yield from Tertiary drift mines is at present below $10,000 a year. In 1909 the Barton drift mine at Loomis was again operated and the total yield from the quadrangle of drift and surface mines was about $7,000. Practically no hydraulic operations are carried on in Tertiary gravels. The greatest yield is derived from the dredging, drifting, and sluicing of Quaternary gravels. Some of these operations are carried on in the canyon of American River a few miles northeast of Auburn, but most of them near Folsom and Michigan Bar. In 1905, in the vicinity of Folsom, $569,124 was obtained from the dredges, $45,000 by drifting, and $36,500 by surface washings. In 1909 the dredging near Folsom yielded $1,500,000 and operations by drifting and sluicing in Quaternary gravels produced $135,000.

TERTIARY TOPOGRAPHY AND STREAM COURSES.

The relief of this quadrangle during the Tertiary period was less pronounced than at present, but the principal features were similar. Then, as now, the Rocklin granitic area was a depression with gently rolling surface. The harder ridges of amphibolite rose about it as now. Northwest of Auburn the Tertiary topography is probably very fairly represented by the flat, granitic ridges of Doty Flat, and by the equally flat amphibolite hills rising some 500 feet above the granitic plateau. The canyons of American River (see Pls. XII, p. 78; XIX, *B*, p. 134) did not exist, but there is every reason to believe that the longitudinal amphibolite ridges of the southwest corner, southwest of Folsom, existed then as now, although later erosion has emphasized their relief. American River has dissected the Tertiary plateau to a depth of 1,500 feet near Auburn, but at Folsom the depth of the cutting is only 400 feet.

The Tertiary American River entered the quadrangle near Pilot Hill and passed through the gap at this place. Remnants of the gravels of the same river are found 2 miles southeast of Loomis and Rocklin, but from this point on the gravels are covered by volcanic masses. During the intervolcanic epoch the Forest Hill watershed was diverted into the American River basin from that of the Yuba. Remnants of the gravels of this stream are found on the point between the North and Middle Forks of American River and about 2 miles south of Auburn.

The grades of the Tertiary River are shown in the subjoined table:

Grades and distances of the Tertiary American River.

Place.	Elevation of bedrock.	Distance.	Grade.
	Feet.	*Miles.*	*Feet per mile.*
Gravel Point, 3 miles northeast of Auburn	1,550		
Haskell mine	1,100	6	75
Gravel hill, 2 miles southeast of Loomis	500	6	100
Lee mine	350	2	75
Pilot Hill	1,250		
Lee mine	350	11	82

DETAILED DESCRIPTION OF THE GRAVELS.

PREVOLCANIC GRAVELS.

Practically the only prevolcanic gravels exposed in this quadrangle are those found 2 or 3 miles east of Rocklin; the exposures extend for about 4 miles northeast and southwest, and are at most 2,000 feet wide. Farther down the slope, about 2 miles southeast of Loomis, there are two small gravel hills at an elevation of 500 feet, the banks being 40 or 50 feet high. No work has been done at this place for a long time. The gravel, which is well washed, consists of medium-sized pebbles of quartz and metamorphic rocks, with a considerable amount of granite sand. The bedrock forms a wide trough 40 or 50 feet deep. Half a mile southwest of this place the gravel reappears and is continuous for 3 miles, to the point where it disappears underneath the volcanic material and clays of the Ione formation. At the Laird mine a thick bank of gravel and sand is exposed.

At the Lee mine, situated where the road from Loomis to Folsom crosses the gravel hills, drifting operations have been in progress for a number of years. The detrital deposit is about 1,500 feet wide, and the gravels 60 feet deep. The deepest channel worked is said to be 350 feet wide, the material being taken out 6 feet high above bedrock; it contains fine and flaky gold, and is treated in a 5-stamp mill. The mine is opened by a vertical shaft, somewhat over 100 feet deep, and the gravel occurs on two levels. The deepest channel, with a bedrock elevation of 350 feet, is stated to lie 50 feet below the "Stone House" along the road and contains chiefly quartz gravel. The upper channel is about on the level of the "Stone House" and contains large cobbles, some of them of Tertiary volcanic rocks. Both channels are said to be rich.

The thirteenth report of the State mineralogist contains an account of the operations of the Barton mine in 1896, evidently located lower down on the same channel. It is stated that

this mine is worked through a vertical shaft 60 feet deep and, lower down along the lead, by an incline 250 feet long. A pump working four hours a day discharges the water. The gravel is disintegrated in a Cox pan.

It is evident that this channel continues underneath the andesite tuff along the slope and that if it proves rich enough it can easily be worked some distance farther west without encountering too heavy bodies of water. It represents the lower reaches of the Tertiary American River and might therefore be expected to be rich.

A small remnant of the washed quartz gravels lies in the important gap at Pilot Hill, but most of the accumulations at this place have been removed by erosion.

INTERVOLCANIC CHANNELS.

The areas indicated as andesite in the Sacramento quadrangle (Pl. I, in pocket) consist of an upper flow of tuff-breccia, under which lie a number of thin beds of fine-grained tuffs, gravels, sands, and clays of volcanic origin. Intervolcanic channels exist underneath Boulder Ridge, northwest of Penryn, underneath the andesitic tuffs south of Auburn, and at several other isolated localities. None of them have proved to be very rich.

On the point between the North and Middle forks of American River, at an elevation of 1,550 feet, lies a small deposit of partly volcanic gravel which has been worked in a small way. It is important as undoubtedly indicating the course of the main intervolcanic channel coming down from Peckham Hill and Jones Hill, on the Forest Hill divide.

Some drift mining has been done on small intervolcanic channels at the Gaylord mine, 2 miles south-southwest of Auburn, at the south edge of a table of andesitic tuff; the elevation is 1,200 feet. A tunnel was driven in a northerly direction for several hundred feet to open a main channel underneath the lava ridge. It was struck at tunnel level, but the well-defined trough was found to be filled with andesitic sand; very little gravel was found, and that of poor grade. The channel was explored for 500 feet upstream without change. Explorations 200 feet northeast from the main tunnel show the existence of a channel at the same elevation as the sand channel, but containing volcanic gravel. This was followed in under the hill for a short distance, but was found to be cut off by the first channel. A third channel, which was mined in 1901, on the east side of the road and at a somewhat higher elevation, is 125 feet wide and contains wash of metamorphic rocks with a few andesite pebbles. Andesite breccia covers the gravel, which is 1 to 6 feet thick. Its southwest rim appears to be washed away by the second channel and its westward continuation is probably cut off by the main sand channel. There are here, then, three channels of slightly differing age but all of them belonging to the intervolcanic epoch.

Several small channels have been worked under Rocky Ridge, on the road between Penryn and Lincoln. Two channels are said to exist. One, the older, is called the White channel and contains many quartz pebbles. It has been worked on the rim along the southeast side of the ridge which it is supposed to follow, but it is stated that its bottom has not been exposed. The second is an intervolcanic channel and is thought to follow the northwest side of the ridge. It has been worked by several tunnels, but in general was found to be poor. Rich spots of $5 to $9 a ton were, however, struck on the rim. The Patterson incline, about 1,000 feet long, has opened it on the northwest side of the ridge near the road, at an elevation of about 900 feet. The gravel is well washed, consisting of andesite, quartz, and greenstone pebbles; its thickness ranges up to 12 feet, and it is directly covered by compact, tuffaceous breccia. Heavy volcanic wash lies on the spurs north and south of the tunnel, but occupies no well-defined channel. It is said to contain some gold and is evidently later than the volcanic channel just described.

VICINITY OF FOLSOM.

Rich Quaternary gravels, up to 60 feet in thickness, have been accumulated at Folsom, both along the present river course and for several miles to the south of the town. They represent several not very sharply defined benches up to elevations of 200 feet above the river and are

underlain by a volcanic series, the exact depth of which is unknown but probably does not exceed 150 feet. These Quaternary gravels have been extensively worked, first by drifting and hydraulic operations, and lately by dredging. Much drifting has been carried on at Rebel Hill, 2½ miles south of the town.

At the Orange Vale Bluffs, opposite Folsom, the following section is exposed above river level:

Section at Orange Vale Bluffs, near Folsom.

	Feet.
Metamorphic gravel, fine and coarse; Quaternary	10
Andesitic tuff-breccia; Neocene	35
Fine andesite tuff; Neocene	10
Fine white clays and sand; Neocene	35
River level.	

The several river bars lower down, which are worked by dredging, are generally bordered on the north by similar gravel-capped bluffs, the andesitic breccia showing only in places. The gravel dredged rests usually on a bedrock of fine-grained andesitic tuff. In places masses of coarse Tertiary volcanic gravel, barren of gold, appear above or below the andesitic tuff-breccia.

Several bore holes and shafts have been sunk near Folsom with the idea of penetrating the volcanic series and reaching the supposedly underlying auriferous gravels. A shaft sunk in 1895 by McCue & Bates a short distance below the town and 60 feet above the river penetrated the following strata:

Section in shaft below Folsom.

	Feet.
Surface.	
Cobblestones and gravel; Quaternary	10
Volcanic tuff; Neocene	40
Gravel with some gold; Neocene	12
Volcanic tuff; Neocene	5.3
Coarse volcanic tuff; Neocene	6
Sand, probably volcanic; Neocene	20
Coarse gravel; Neocene	6
Gray sand (fossiliferous); Chico (Cretaceous) (?)	20
	119.3

The influx of water stopped further progress.

The Quaternary high bars of American River have been worked extensively. Especially rich are the deposits near Mormon Island and the Blue Ravine mine. The latter was successfully worked in 1907 through a 60-foot shaft.

CHAPTER 15. THE PLACERVILLE QUADRANGLE.

GENERAL GEOLOGY.

The geology of the "Bedrock series" of the Placerville quadrangle is complicated. The western margin is followed by a belt of the Calaveras formation, greatly broken by later intrusions and in part accompanied by greenstone tuffs of Carboniferous age. The late Jurassic Mariposa formation, accompanied by large masses of Jurassic greenstones and greenstone tuffs, traverses the western area in a narrow band from north to south. East of these rocks the Calaveras formation, having its prevailing northerly trend, occupies the greater eastern part of the quadrangle. A large area of gabbro-diorite lies near the western margin; numerous serpentine areas of elongated form are found in the same vicinity. The south end of the great gabbro-serpentine belt of Downieville and Colfax quadrangles traverses the north-central part of this area from Placerville to Georgetown. The main granitic area of the high Sierra enters the Placerville quadrangle at several places along its eastern margin. Four granitic "massifs" or batholiths, referred to as Sand Mountain, Mosquito, Coloma, and Cosumnes, have formed great rents in all of the older formations.

The superjacent formations do not occupy very large areas. Tertiary auriferous gravels appear near Placerville. Rhyolitic tuffs lie in the old stream beds on the Long Canyon divide and especially underneath the Placerville and Newtown divides. Andesitic tuff-breccias cap many of the ridges from the Cosumnes to Long Canyon, but the largest masses are found on the Placerville and Newtown divides. No Tertiary or post-Tertiary dislocations have been found in this quadrangle. The whole area has been tilted westward, but the Tertiary channels give excellent evidence that no important faulting has occurred.

GOLD-BEARING AREAS AND PRODUCTION.

Gold is widely distributed throughout the quadrangle, and few of the creeks have proved entirely barren. The least productive area is located in the large slate region in the northeastern part of the quadrangle, and naturally the late flows of andesitic rocks do not contain gold-bearing deposits. The most important line of primary deposits follows the Mariposa formation from south to north and forms an extension of the great Mother Lode belt of Amador and Calaveras counties. Many quartz mines are located along it.[1] Small auriferous veins are very likely to be found about the contacts of the intruded granitic masses. The most important of these minor districts is that at Grizzly Flat.

The "serpentine belt" is here, as farther north, followed by a great number of small quartz veins. From these veins the small Tertiary placers of Georgetown have been enriched, but the more extensive gravels at Placerville owe their concentration of gold chiefly to the veins of the Mother Lode belt.

On the whole the gravels of the eastern half of the quadrangle are poor. The mining operations in the Placerville quadrangle are practically equivalent to those of Eldorado County. This county produced in 1905 about $250,000 from deep mines, $2,900 from hydraulic operations, $58,685 from drifting, and $27,788 from surface sluicing, a total of $89,373 from placer operations. The yield from gold-bearing gravels has steadily and slowly decreased for several decades. In 1905 the output from placers was approximately divided as follows: Placerville (six drift mines), $64,900; Indian diggings, $7,000; Georgetown (two drift mines and several surface placers), $6,900; Fair Play (two drift mines and several surface placers), $4,450;

[1] See Placerville folio (No. 3), Geol. Atlas U. S., U. S. Geol. Survey, 1894, economic geology map.

scattering, $6,578. In 1908 drift mines in the county yielded $38,148, hydraulic mines $2,600, and surface mines $96,106—a total of $136,854. The drift mines at Placerville produced about $19,500; the placer mines at Fair Play and Omo House about $8,000 and at Grizzly Flat $19,000. More than half of the amount was obtained by small operators, mostly Chinese.

In 1909 the placer mines near Placerville yielded $32,500, the most important producers being the Eldorado Water & Deep Gravel Mining Co. and the operator of the Landecker mine. Both of these producers operate drift mines. From the vicinity of Georgetown and Greenwood $24,000 was obtained, mainly from sluicing operations. From the Fair Play divide the yield was $5,900, chiefly from sluicing. Scattered operations at Shingle, Pacific, and other places yielded $3,000.

TERTIARY TOPOGRAPHY AND DRAINAGE.

The Placerville quadrangle, embracing a typical part of the lower slope of the Sierra Nevada from the lower foothills to elevations of about 5,000 feet, offers exceptional opportunities for a study of the Tertiary surface.

Standing on the level ridge of andesitic tuff at Forest Hill, at an elevation of 3,100 feet, and looking southward over the Georgetown divide—the northern part of the Placerville quadrangle—the observer notes the apparent continuation of the lava plateau across the deep canyon of American River. But beyond this the high ridges of the Slate Mountains rise in decided relief. The channels of the deep gravel-filled basin of Forest Hill lie about 400 feet below the summits of the tuff ridges; 10 miles to the southwest the Slate Mountains culminate in elevations 2,000 feet above this basin, and the volcanic areas surrounding their base attest to a diversified topography. The same conditions of high relief continue eastward to the margin of the quadrangle, the ridges rising on the average 1,000 feet above the broad Tertiary river valleys.

In the middle part of the quadrangle lies the deep Tertiary basin of Placerville, several miles wide, with a complicated channel system hidden underneath gravel rhyolitic tuffs and andesitic tuffs, and slopes rising gently 400 or 500 feet above the lowest depressions. From some prominent point near Placerville the gradually rising highlands to the north and south of the Tertiary basin of American River are plainly perceived. To the northwest the Tertiary river course is unmistakably marked by way of Granite Hill and Pilot Hill; this is the only way open, for to the west a series of distinctly higher, north-south bedrock ridges effectually bar an old outlet in that direction. The contrast was of course even more decided in early Tertiary time because the range was not then as strongly tilted toward the west as it is now. Here, again, we thus find the feature of the high foothill ridges already described in the chapters on the northern quadrangles. Near the eastern border of this quadrangle the Tertiary American River flowed in a broad valley; 6 miles to the north of it Saddle Mountain rose 2,000 feet above its bed, and 4 miles to the south Baltic Peak attained an elevation of 1,700 feet above it.

In the southeast corner a branch of the Tertiary Mokelumne River flowed over a moderately hilly country in a southwesterly direction by way of Grizzly Flat, Henry Diggings, Brownsville, and Oleta.

AURIFEROUS GRAVELS.

As in the Colfax quadrangle, there are in this area prevolcanic gravels, gravels of the rhyolitic epoch, and gravels of the andesitic epoch.

The prevolcanic gravels consist of well-washed pebbles of quartz and metamorphic rocks. The thickness of these deposits is small compared to that of the heavy accumulations in the great Tertiary basin of Yuba River from Forest Hill to North Columbia. The gravels in the Placerville quadrangle very rarely attain 100 feet in thickness; much more commonly they are 25 to 50 feet thick.

RHYOLITIC BEDS.

The rhyolitic beds directly overlie the auriferous gravels and are composed of white or light-colored tuff, usually fine grained and here and there containing scales of black mica. This volcanic fragmentary material doubtless came down in the form of many successive mud flows.

Intercalated in the tuffs are beds of quartzose and metamorphic gravel and of light-colored clays and sands partly of volcanic origin. The gravels are as a rule somewhat auriferous. The total thickness of the rhyolitic beds is about 300 feet on the divide north of Long Canyon and 400 feet in the vicinity of Newtown. Unlike the subsequent volcanic flows, the rhyolite did not spread over large areas, but only filled the valleys of the principal streams. During the interval between the rhyolitic eruptions the earlier beds were considerably eroded and in many places new channels were worn down to the bedrock. These later channels occur both north of the Middle Fork of American River and especially in the vicinity of Placerville.

In the Tertiary valley of American River a very large proportion of the prevolcanic gravels was eroded during the earlier part of the rhyolitic epoch, and by far the greatest masses of gravel now exposed belong to this class of rhyolitic channels.

ANDESITIC TUFFS.

The andesitic eruptions in the high Sierra flooded the larger part of the lower slopes with volcanic mud. Substantially the whole of the Placerville quadrangle must have been thus covered, except the high bedrock ridges of the Slate Mountains and, probably, the hills in the southwest corner.

The andesitic beds, which are entirely fragmental in character, attain a maximum thickness of 700 feet on the divide north of Long Canyon; in the vicinity of Placerville the thickness does not exceed 400 feet, but east of Placerville it again increases to 700 feet. In the lower part of the bed heavy volcanic gravel, in many places somewhat auriferous, commonly occurs, together with volcanic sands and tuffs; the upper and principal part consists of a hard andesitic breccia and usually contains angular or subangular bowlders of andesite, some of which are more than a foot in diameter. The andesite is dark gray to dark brown and contains porphyritic crystals of pyroxene and hornblende, the latter slightly predominating; the cement uniting the bowlders is light gray to light brown and consists of finely comminuted volcanic material.

The conditions during the andesitic eruptions were similar to those of the rhyolitic epoch, for during quiet intervals the streams, rejuvenated by the tilting of the Sierra, eroded vigorously and reconcentrated the old gravels. Such interandesitic channels are present in the old basins of all parts of the quadrangle. They are most important in the northwestern part, where an important channel of this kind captured a part of the Forest Hill drainage, which before the eruption belonged to Yuba River. They are not of much importance in the Placerville basin, where such opportunities of stream capture were not afforded any more than in the northern part of the Yuba River basin.

DETAILED DESCRIPTION OF THE GRAVELS.

GEORGETOWN DIVIDE AND PECKHAM HILL.

A well-defined Tertiary valley with a general south to north direction existed northeast of Georgetown, with hills rising 1,000 feet above it 2 miles to the east and about 500 feet above it 1 mile to the west. It is first observed at Tipton Hill, 5 miles east-northeast of Georgetown. The bedrock elevation here is 3,200 feet; the narrow channel is covered by 4 to 6 feet of well-washed gravel with some quartz bowlders; above this lies 3 to 4 feet of clay, which in turn is capped by andesitic tuff. This channel has been mined northward by tunnels, one of which is 1,800 feet long, and it is said that several benches were found up to 500 feet above the deepest channel. Some work has also been done about one-fourth of a mile east of Tipton Hill. Two miles farther north the channel is cut by Otter Creek; on the north side of this narrow canyon lies Kentucky Flat. Both outlet and inlet have an elevation of 3,100 feet, showing a grade of 50 feet to the mile from Tipton Hill. Some hydraulic work and drifting have been done at Kentucky Flat; the channel is 350 to 500 feet wide and filled to a depth of 4 to 6 feet with well-washed gravel and large, smooth quartz bowlders. Silicified wood is common.

Two miles farther due north the channel is cut by Missouri Canyon at an elevation of 3,100 feet. There is little evidence here of the white quartz channel, which most likely has

suffered some erosion. But it is stated on the authority of H. E. Picket, manager of the Two Channel Mining Co., who has been operating drift mines in this vicinity during the last few years, that "cement channels," or intervolcanic channels, exist here and that their direction differs from that of the white channel. The latter probably continues underneath the volcanic area to the north of Missouri Canyon and most likely emerged on the slope of the canyon of the Middle Fork a mile to the northwest of Mount Gregory and continued across the now eroded canyon toward Forest Hill. The elevation of the supposed outlet is about 2,850 feet—too high, it will be noted, to effect a junction with the white channel of Michigan Bluff, with which it is often identified.

The andesitic or cement channel doubtless turned to the northwest and continued by way of Floris Hill in the general direction of the present Middle Fork Canyon until it joined the cement channel from Forest Hill, which had cut its way through a low gap and found its outlet at Peckham Hill, as decribed in the chapter on the Colfax quadrangle. There are in this vicinity several small patches of volcanic gravel on the spurs of the ridges overlooking the Middle Fork, such as Jones Hill, Bottle Hill, and others. Their elevation and general character agree well with the supposition of a cement channel as outlined above.

Elevations, grades, and distances along the Georgetown channel.

Place.	Elevation.	Distance.	Grade.	Direction.
	Feet.	*Miles.*	*Ft. per mile.*	
Tipton Hill	3,200			
Kentucky Flat	3,100	2	50	South to north.
Missouri Canyon	3,100	2	0	Do.
Mount Gregory	2,850	1.5	166	Southeast to northwest.
Floris	2,530	3	107	East to west.
Jones Hill	2,114	a 5	83	West-southwest to east-northeast.
Peckham Hill	2,183			

a Junction.

LONG CANYON.

A small bend of the Long Canyon channel falls within this quadrangle. It occupies a wide and deep valley filled with a great thickness of rhyolitic tuffs and gravels poor in gold. The prerhyolitic gravels are very thin. The deposit reached its greatest width near the junction of Wallace and Long canyons, where the old river bottom must have been about 2 miles across. The old Clydesdale diggings lie on a point between the two canyons opposite Blacksmith Flat and south of Wallace Canyon is the detached deposit of the Corcoran diggings. South of this the slope of the Tertiary valley rises very steeply, almost like a bluff.

An important tributary, but one very poor in gold, joined the Long Canyon channel somewhere between Pat Goggin's diggings and Michigan Bluff. Its upper continuation is found underneath the cap of andesitic tuff on the high ridge between Pilot Creek and Rubicon Creek. Near the point of that ridge, on the north side and at an elevation of 3,600 feet, a few feet of quartzose gravel underlies the andesite. The old depression continued up southeast by way of Bacchi's and Forni's ranches, then turning east up to Eleven Pines and Uncle Toms Cabin. It has not been shown to contain paying gravel deposits.

THE TERTIARY AMERICAN RIVER.

The channel of the Tertiary American River entered this quadrangle near Pacific House, on the road from Placerville to Lake Tahoe, and here lies only 500 feet above the bottom of the Middle Fork Canyon. On the north side of the river is a small hill of gravel and rhyolite tuff (elevation 3,500 feet), in which a hydraulic cut has been made, with what result is not known to the writer.

A distinct trough at Pacific House, about half a mile wide and 150 feet deep, is filled with rhyolitic tuff. The deepest point (elevation 3,400 feet) lies just below Pacific House, and some little hydraulic work and prospecting by drifting have been undertaken in it. The gravel is coarse

and well washed, consisting of quartz and metamorphic rocks, not over 10 feet deep and immediately covered by rhyolite tuff, with some intercalated minor gravel beds. Above the rhyolitic tuffs lie andesitic tuffs with a thickness of 500 feet. The old river valley was about 3 miles wide and the immediately surrounding hills rose 700 or 800 feet above the bottom.

Some gold undoubtedly occurs in the gravels, but it is questionable whether the channel will pay for working. In the last few years a bedrock tunnel has been driven near Pacific House to explore the channel, but no detailed information is available.

A tributary channel crossed the South Fork a few miles to the west; it came down from the head of Round Tent Canyon and had its outlet on the north side near Soldier Creek; it is probably not highly auriferous.

The main channel continues underneath the lava flows and finally reappears 10 miles west-southwest of Pacific House, at Snow's mine, near Newtown. As shown by the outcrops of rhyolite tuffs it passes close to Sly Park Creek, but no outbreaks of gravel are known. A tributary channel from Badger Hill on the north joins it by way of Mooney's diggings, in the North Fork of Webber Creek. At Badger Hill the elevation of the channel where it crosses underneath Big Iowa Canyon is 3,000 feet, and it has been worked with some success. The gravels occur both above and below the thin bed of rhyolite tuff exposed in the canyon. At Mooneys Flat the channel lies at an elevation of about 2,900 feet, perhaps 100 feet beneath the creek. It was opened by an incline 50 feet deep, but the wash gravel is reported not to have been rich. Some higher benches above the creek level have been sluiced.

The main andesitic ridge continues westward toward Placerville, but it does not cover any main channel. On the contrary the bedrock is generally high on the north side and the andesitic tuff simply covers the northern slope of the main valley. The Blair tunnel (elevation 2,700 feet), 2 miles east of Six Mile House, was driven northward for several thousand feet on the erroneous idea that the main channel followed this part of the ridge.

At Snow's mine, 8 miles east of Placerville, the main channel from Pacific House has its outlet at an elevation of 2,400 feet. The gravels at this place are meager in extent and only 4 to 8 feet in thickness; large masses of gravel have probably been removed by interrhyolitic erosion. Both drifting and hydraulic operations have been carried on here on a small scale, and it is quite possible that the channel can be drifted upstream from this point.

The gravels of the Webber Creek basin above Placerville are, on the whole, poor. From Snow's the channel crosses to the south side of Webber Creek and continues under the ridge below Newtown, issuing again at some point along the gravel banks west of that place. It then follows the general trend of Webber Creek westward, as clearly shown by the bedrock relation on both sides of that stream. The lowest point seems to be indicated by a small body of wash on top of the low ridge between the two forks of Webber Creek (elevation about 2,350 feet) and the isolated area 2 miles southeast of Smiths Flat (elevation 2,250 feet). For 2 miles west of Newtown, as far as Fort Jim, bench gravels are exposed at an elevation of 2,500 feet; on the north side of Webber Creek similar benches are exposed on both sides of Chunk Gulch at elevations of 2,400 to 2,450 feet, the width of the flood plain having been nearly 2 miles.

All the gravel areas of Placerville lie distinctly to the north of the principal channel, which has been destroyed by erosion. The lowest bedrock elevation near Placerville is 1,898 feet, at Webber Hill; a small gravel mass at Bean Hill, on the south side of Webber Creek, near Diamond Springs, has an elevation of only 1,777 feet. The isolated gravel areas of Diamond Springs and Bean Hill may, then, be taken to represent the course of the main river. The last traces of the channel in this quadrangle are found at Granite Hill, on the divide between Webber Creek and the South Fork of American River, where the lowest bedrock elevation is about 2,650 feet. From the present topography at this gap it is concluded that the flood plain was 2 miles wide, with hills rising very gently on each side.

From this place the only possible outlet is by way of the Pilot Hill gap, all other directions being closed by the high bedrock hills of the greenstone range of the foothills.

Elevations, grades, and distances along the Tertiary American River in the Placerville quadrangle.

Place.	Elevation.	Distance.	Grade.	Direction.
	Feet.	*Miles.*	*Feet per mile.*	
Pacific House	[a] 3,400			
Snow's mine	[a] 2,400	10	100	West-southwest.
Newtown	[a] 2,350	1	50	West.
Gravel Hill, south of Webber Creek	[b] 2,250	2	50	Do.
Bean Hill	[c] 1,777	5	105	Do.
Granite Hill	[a] 1,650	5	25	North-northwest.
Pilot Hill	[c] 1,250	9	33	Northwest.

[a] Lindgren. [b] Possibly too high. [c] Goodyear, W. A., in Whitney's "Auriferous gravels."

The dependence of direction on grade is markedly indicated by this table. There is, of course, some uncertainty about the elevations but not enough to seriously affect the result. Those parts of the channel which trended west or west-southwest have generally grades of 50 to 100 feet to the mile; that part trending north-northwest only 25 feet to the mile; a division trending northwest has a somewhat intermediate grade.

It has been shown that from a point near Newtown to Granite Hill only fragments remain of the deposits of the Tertiary river. There are scarcely any prevolcanic gravels within this distance, the criterion being the absence of volcanic pebbles. Bean Hill seems to be the only place where volcanic pebbles occur, and even here there is a doubt. The writer could find no rhyolitic pebbles at this place, but Goodyear distinctly states that they are present. The principal gravels of the district are of the interrhyolitic epoch, but there are also some of the interandesitic epoch.

Near Newtown the rhyolitic tuffs reach a thickness of 500 feet. Fairly extensive hydraulic operations have been carried on at several places near Newtown. On the lowest bedrock rest about 30 feet of gravels consisting of quartz, granite, metamorphic slates, and rhyolitic tuff. This gravel bed is covered by 40 feet of white tuff, and above this lies another gravel bed, 60 feet thick, which in turn is capped by the main mass of the same tuff, which always has a tendency to form prominent bluffs. At Fort Jim, 1 mile west of Newtown (bedrock elevation 2,450 feet), 10 feet of possibly prevolcanic quartz gravel is covered by 100 feet of coarse mixed gravel and this in turn by thick accumulations of rhyolite tuff.

Contrasting with these sections is the gravel hill 3 miles west-northwest of Newtown, which, according to its elevation (2,250 feet), is near the deepest point in the old valley. Here a moderate thickness of gravel is covered by a thin bed of rhyolite tuff, which in turn is capped by andesitic conglomerate, showing that deep erosion of the rhyolitic beds occurred before the andesitic flows began.

At Diamond Springs, 3 miles south of Placerville, the gravel is 50 feet thick and contains many rhyolite bowlders.

At Granite Hill all of the gravel contains rhyolite, the succession being as follows:

Section of gravel at Granite Hill.

	Feet.
Gravel	4
Rhyolitic tuff	50
Gravel	20
Rhyolitic tuff	4
Gravel	6
Bedrock.	

PLACERVILLE BASIN.

GENERAL NOTES.

The Placerville district is situated on the ridge between the South Fork of American River and Webber Creek and contains a complicated network of channels, in the main trending south and tributary to the Tertiary, now eroded river, which approximately followed the course of Webber Creek. These gravels have been studied by Goodyear [1] and his description contains

[1] Goodyear, W. A., in Whitney, J. D., Auriferous gravels, pp. 98–105, 500–504.

much valuable and accurate information. In the main he recognized the principal drainage lines described above, the Deep Blue channel, and the general occurrence of bowlders of rhyolitic tuff in the deeper gravels. But his examination was made many years ago, and the following data collected in 1901 are therefore presented. Mr. G. W. Kimble, who is perhaps better acquainted with the Placerville basin than anyone else, had the kindness to aid the writer in many ways and put valuable maps and sections at his disposal.

The Placerville basin has been a rich placer field. The modern creeks yielded a large amount, and when the exploitation of the high gravels was begun these also were found to be very productive. The great complex of veins, called the Mother Lode of California, traverses the western part of the district from north to south. It is well exposed at Oregon Point, almost due south of Placerville; traverses the center of the town, where the Pacific mine is located; and then follows the course of Big Canyon, which contains the Harmon and Little Annie mines. Many small quartz veins are contained in the slates outside of the Mother Lode, but the latter was really the most important factor in the enrichment of the gravels below the croppings. The richest gravels of Placerville were those of Coon Hollow and Excelsior, just west of the Mother Lode. According to the statement of Mr. T. Alderson, a pioneer merchant and miner of the district, this vicinity yielded about $10,000,000 from a comparatively small area. The gravels of Spanish Hill yielded $6,000,000 and those of the White Rock diggings $5,000,000. The Linden channel, traversing the ridge south of Spanish Hill, yielded $130,000. The Deep Blue lead from White Rock to Smiths Flat has yielded heavily, one of the properties, the Lyons mine, having produced $1,400,000 by drifting. The Deep Blue lead followed approximately for several miles the contact of the slate with the Mosquito area of granodiorite, and probably derived its riches from many small veins in the contact zone. The gravels from Smiths Flat down to the Mother Lode are not extremely rich, averaging by drifting perhaps $2 to $3 a cubic yard. Those of Coon Hollow were of very much higher grade. The whole mass of gravels mined at Coon Hollow, a thickness of at least 100 feet, is believed by Mr. Alderson to have averaged $1 a cubic yard. In 1905 the output from the drift mines of Placerville was $65,000. Seven or eight producers contributed to this amount, the three most important being the Landecker, the Ribera tunnel, and the Liveoak.

GEOLOGIC FEATURES AND PRINCIPAL CHANNELS.

The general geology in the vicinity of Placerville is shown in the Placerville folio.[1] Gold-bearing gravels, rhyolitic tuffs, andesitic tuffs, and andesitic gravels cover the ridges surrounding the basin of Hangtown Creek, in which Placerville is situated. The principal channels are shown in figure 13.

South of Placerville Hangtown Hill rises to an elevation of 2,196 feet. The ridge extends with gentle rise across the Excelsior cut; about 1½ miles farther east it rises more steeply to Cedar Creek Hill, the elevation of which is 2,400 feet. It is capped by andesitic tuff and gravels, resting on bedrock or in places possibly on older prevolcanic gravels. At its east end heavy masses of rhyolite tuff underlie the andesitic rocks. A deep sag covered by rhyolite tuff at the head of Cedar Creek separates this ridge from the Spanish Ridge, which begins at Spanish Hill (elevation 2,300 feet) and extends to a point south of Smiths Flat (elevation 2,600 feet) about 2¼ miles east and west. It is capped by andesitic tuff and underlain by rhyolite tuff. Another gap of rhyolite intervenes at Smiths Flat, to the north of which extend the White Rock Ridges capped by andesitic tuffs. These connect with the main lava-covered ridges of eastern Eldorado County and rise gradually toward the east-southeast from elevations of 2,400 at Negro Hill and Georgia Hill to 3,000 feet at Six Mile House.

The thickness of the andesitic tuffs and gravels aggregates up to 400 feet. The white rhyolite tuffs reach a maximum of 300 feet in thickness in the steep bluff east of Smiths Flat. The thickness of the rhyolite tuff varies considerably from place to place, indicating the great amount of intervolcanic erosion.

[1] No. 3, Geol. Atlas U. S., U. S. Geol. Survey, 1894.

The Tertiary interrhyolitic gravels attain a thickness of over 100 feet in the Tertiary depression near Placerville; on the ridges east of Smiths Flat the andesitic tuff as a rule rests directly on the bedrock, indicating highlands from 300 to 600 feet above the valleys.

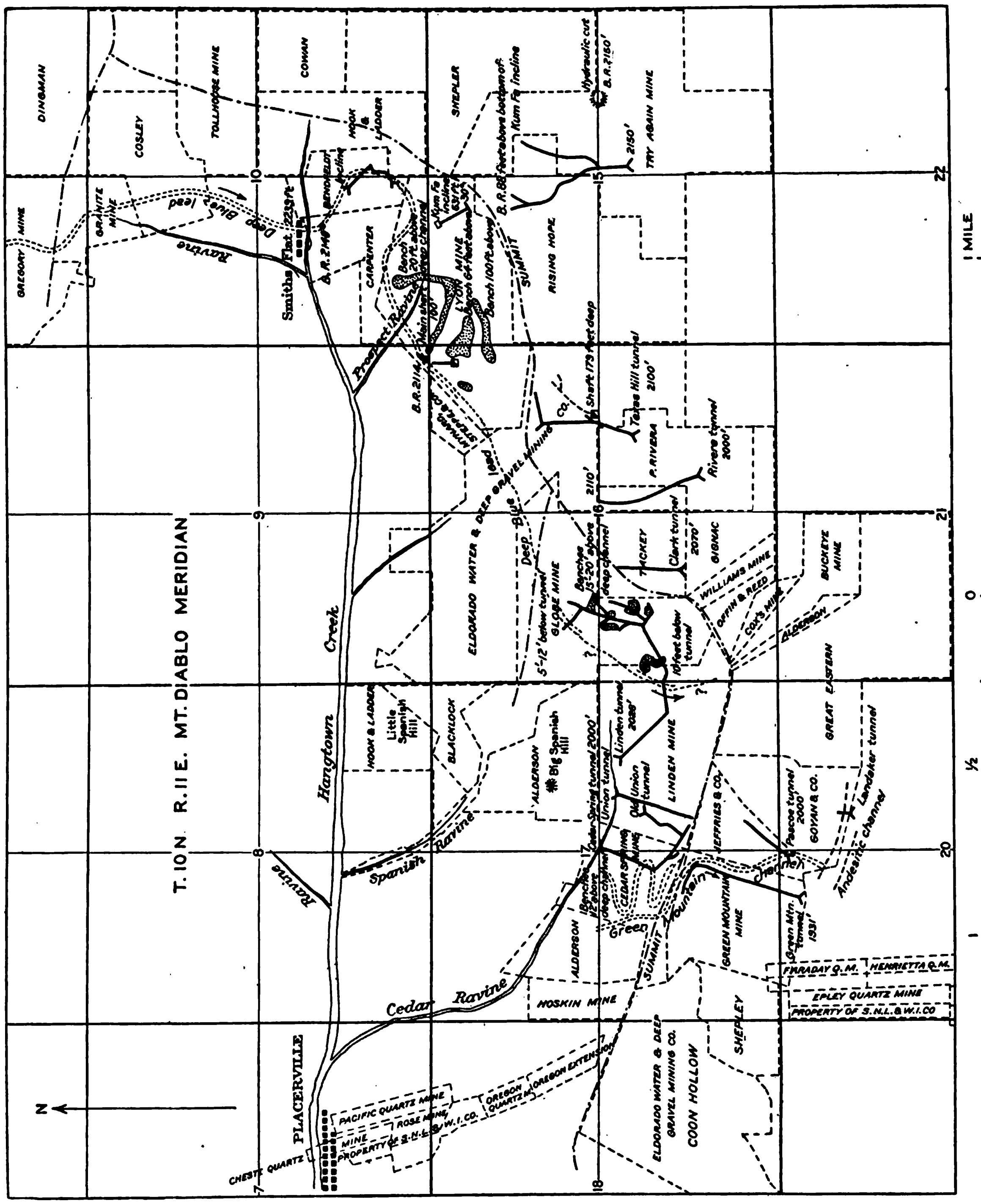


FIGURE 13.—Map showing the principal gravel channels near Placerville. Outlines of claims from map by R. Rowland in Twelfth Report of the California State Mineralogist.

Prevolcanic gravels are very sparingly represented in the Placerville basin. There is reason to believe that some bench gravels in Coon Hollow were accumulated before the rhyolite, and more of such gravels may have been contained in the now eroded main channel of the Tertiary

river which followed the course of Webber Creek. Practically all the pay gravels belong to the rhyolitic epoch and were accumulated in streams flowing southward and tributary to the main river. These interrhyolitic gravels belong to several subepochs, some of the earlier deposits forming long swinging benches with low grade. Somewhat later the grade was increased and the last and deepest of the interrhyolitic gravels were deposited. After the first andesitic flows thick deposits of barren andesitic gravels formed a flood plain over a large part of the basin. Still later interandesitic, narrow channels, usually poor in gold, were excavated, but they are of little importance and did not cut deeply into the bedrock of the interrhyolitic epoch.

On the south or Webber Creek side of the ridge there are many benches of interrhyolitic gravel which evidently belong to the main river. There are also two important interrhyolitic southward-trending channels which have been successfully mined; one of them is the Linden and Green Mountain channel west of the Cedar Creek gap, and the other is the Deep Blue channel, which comes down from Georgia Hill underneath the lava ridge to Smiths Flat and has its outlet at some point about a mile south of that place. The two channels are separated by a ridge of slate rising about 300 feet above their beds. The elevations given are based on Goodyear's data, as given in Whitney's "Auriferous gravels," but are supplemented by numerous aneroid determinations and mine levels. The elevation at Clay Hotel in Placerville is taken to be 1,873 feet.

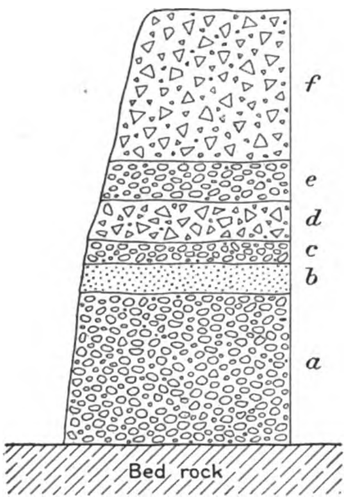


FIGURE 14.—Section at hydraulic cut on Hangtown Hill, Placerville. *a*, Andesite gravel, 30 feet; *b*, sand, 4 feet; *c*, andesite gravel, 3 feet; *d*, andesite tuff-breccia, 6 feet; *e*, andesite gravel, 6 feet; *f*, andesite tuff-breccia, 25 feet.

HANGTOWN HILL.

Hangtown Hill and the Cedar Hill Ridge are capped somewhat uniformly by 25 to 50 feet of normal andesite breccia, as a rule hard and compact, though in places deeply decomposed on the surface. Below this is throughout 50 to 100 feet of andesite gravel, usually coarse and compact, a very large proportion of the pebbles being over 6 inches in diameter. Streaks of sand are found here and there in this volcanic gravel, and also metamorphic pebbles, the latter most commonly on bedrock. On the west side of Oregon Point many heavy and well-washed quartz bowlders lie on the bedrock.

At the west end of Hangtown Hill the bedrock rises to 2,200 feet and has only a thin covering of andesite breccia. Between the end of the andesite and the road lies the small interandesitic Star channel crossing the ridge from north to south. It has been drifted through the hill for 2,000 feet and shows 4 to 6 feet of mixed volcanic rock and metamorphic gravel covered by volcanic gravel. The elevation on the north side is 2,025 feet; on the south side, 2,000 feet; the grade is 62 feet to the mile.

Along the whole front in Coon Hollow, from Oregon Point to the Star channel, the bedrock is very level, ranging from elevations of 2,000 to 2,040 feet. From the road westward up to Oregon Point this rim has been hydraulicked and the section is similar (fig. 14). The bedrock rises distinctly toward Oregon Point, where the big quartz reef of the Mother Lode goes under the Tertiary deposits at a bedrock elevation of 2,090 feet. All along this distance the bedrock pitches slightly southward and a little drifting has been done wherever the volcanic gravel is mixed with metamorphic gravel and quartz.

EXCELSIOR.

From the north front the bedrock slopes gently southward toward the Excelsior claim in Coon Hollow. A little farther on toward Excelsior there is a well-marked sharper slope or bench, evidently running all the way round to the Webber claim, showing clearly that the Excelsior channel does not enter the hill, under the lava cap. At Excelsior Flat, where the

lowest bedrock elevation is 1,985 feet, quartz gravel was very abundant, and in all about 20 acres has been washed away. The gravel contained three pay streaks, the first on bedrock, the second 25 feet above, and the third 60 feet above. (See fig. 15.) The second channel was poorer and not drifted; the first and third were very rich. The total width of the Coon Hollow channel on bedrock was 2,000 feet. The third pay streak was 300 feet wide. According to Mr. Alderson, the yield of the whole hill, including the upper bed of volcanic gravel, was $1 a cubic yard. The drifting at Coon Hollow was done from 1852 to 1861. The whole hill was hydraulicked from 1861 to 1871. Part of the gravel was cemented. The gold on the bedrock was smooth and pretty coarse, its value being $19.10 an ounce. The gold from the upper streak was finer, averaging $20 an ounce.

Mr. Alderson says that the Excelsior gravel carried no volcanic pebbles of any kind, and with this Goodyear seems to agree. There is no rhyolite at any place west of Webber Hill.

The most plausible and, so far as the writer can see, the only explanation of the relations outlined above is that the Excelsior and Webber claims were covered by prevolcanic gravel remaining on a broad and flat bench, on the north side of the main river. Just before the rhyolite eruption the channel was deepened and a lower flood plain established. The first rhyolite now came down, filling the lower flood plain but missing the Excelsior bench. Repeated erosion cut down deeper and finally the largest rhyolite flow filled the valley to a level of 2,150 feet at the head of Cedar Creek. The gravels of the Excelsior claim had a maximum elevation of 2,050 feet and being on the north, flat side of the river barely remained above the rhyolite flow. The broad, flat valley was here easily 2 miles wide. Excelsior and Hangtown Hill probably represent exactly the surface of a part of the valley—a succession of broad benches. But after the rhyolite flows a very broad channel of andesitic gravel filled the whole valley.

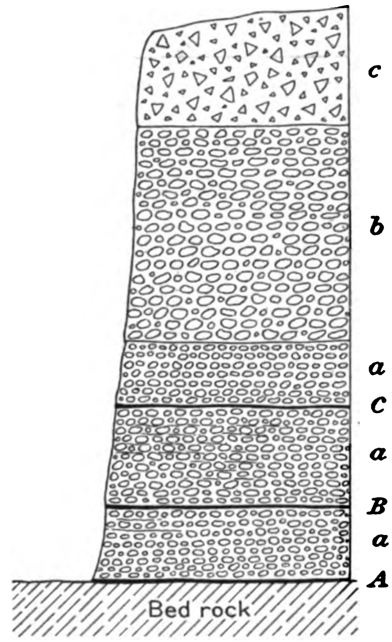


FIGURE 15.—Section at Excelsior claim, Placerville. *A*, *B*, *C*, First, second, and third pay streaks. *a*, Quartz gravel, 60 feet; *b*, andesite gravel, 65 feet; *c*, andesite tuff-breccia, 35 feet.

The projecting spur of the Mother Lode toward the east probably also served to protect Excelsior from a covering of rhyolite.

CEDAR SPRING AND GREEN MOUNTAIN CHANNELS.

At the head of Coon Hollow the bedrock begins to pitch off and a shaft 100 feet deep started at an elevation of 2,040 feet failed to find it. This is the beginning of the Green Mountain and Cedar Spring trough. East of Oregon Point the bedrock also begins to sink and rhyolite appears. At the supposed inlet of the Cedar Spring channel the elevation is 2,010 feet; this is a few hundred feet east of the Cedar Spring tunnel, 1 mile southwest of Placerville. At this hydraulic pit a few feet of coarse gravel with many rhyolite bowlders is capped by 50 feet of rhyolite tuff. Thirty feet above the lowest bedrock is the Missamore tunnel, in which new drifting was done in 1901 on a bench 20 to 30 feet above the deep channel; another bench is still higher. Four feet of quartz and metamorphic gravel with a few rhyolite pebbles is capped by a bed of pink rhyolite tuff. In the deep ground the channel contains, according to Mr. G. W. Kimble, 20 feet of gravel with many rhyolite bowlders; this is covered by 70 to 150 feet of rhyolite tuff. The gravels on the curving bench contain more quartz gravel and fewer rhyolite pebbles and appear rusty, as if exposed to the air for a long time. From the Cedar Spring or Dickerhoff tunnel (elevation 2,000 feet), the long swinging benches 10 to 12 feet above the main channel have been mined. The tunnel is 900 feet in length and is continued by a 75-foot incline

26 feet in vertical depth. The total tunnel grade is 7 feet, consequently the elevation of the channel at the end of the tunnel is 1,981 feet. Goodyear states that in the Cedar Spring tunnel the channel is at first 300 feet wide but soon expands to between 500 and 600 feet. It is very crooked, and the bedrock rises steeply on each side 40 to 60 feet. The pay gravel is from 4 to 6 feet thick.

Connection has been made through the hill with the Green Mountain tunnel, the portal of which is situated on the south side of the ridge. The elevation of the deep channel at the Green Mountain tunnel is 1,948 feet, or 17 feet above the tunnel. From the Green Mountain tunnel the same channel has been mined southward for several hundred feet, going below Pascoe's mill and as far as the divide south of Chile Ravine. From the Pascoe tunnel, which starts in bedrock at an elevation of 2,000 feet, one-fourth mile northeast of the Green Mountain tunnel, bench gravel without rhyolite cobbles has been mined. Such cobbles appear, however, farther in the hill in the same tunnel, on a bench 75 feet above the deep channel.

The deep channel has a grade of about 50 feet in a little less than half a mile, or about 110 feet to the mile, the general direction being from north to south. The swinging benches have a much smaller grade. In 1901 the deep channel had not been mined under the ridge south of Chile Ravine, but it extends through to some point not yet exactly determined on Webber Hill. In a letter of 1911 Mr. G. W. Kimble states that the Green Mountain channel is now practically worked out.

A later andesitic channel of no great value appears to run from east to west along this south front of the hill.

SPANISH HILL.

The flat at the head of Cedar Creek, northeast of the Linden tunnel, is covered with "white lava" or rhyolite tuff; one point of bedrock is exposed which probably is on the rim dividing the Green Mountain and Linden channels. North of the Cedar Spring tunnel rises Big Spanish Hill, the bedrock of which is 25 feet higher than that at the inlet of the Cedar Springs channel. High bedrock is found on the rim above Little Spanish Hill, with elevations up to 2,308 feet. This high rim descends abruptly to the bedrock of the pit, which has an elevation of 2,170 feet. The hydraulic bank shows 60 feet of white rhyolite tuff covered by andesite tuff. There is no deep channel on Big Spanish Hill corresponding to the deep Green Mountain channel, and the gravels probably lie on a bench that is considerably higher than the deep channel and rises to Little Spanish Hill. Three deep crevices rich in gold traversed the bedrock in Big Spanish Hill. It is uncertain whether they were cracks or fissures or water channels.

The stream outlined by Spanish Hill, Cedar Springs, and Green Mountain formed a well-defined tributary to the main channel in Webber Creek, separated from Coon Hollow on the west and from the Deep Blue lead on the east by high bedrock. The absence of andesite gravel and of all late andesite channels is noteworthy. There is a great thickness of rhyolite tuff. The main character of the channel is the same as that of the Deep Blue lead—a deep rhyolite channel and broad, swinging benches.

DEEP BLUE LEAD AT WHITE ROCK CANYON.

The first point where the Deep Blue lead appears is at Georgia Hill, overlooking the South Fork of American River on the east side of White Rock Canyon. Here a fraction of the channel is preserved, swinging off again on the canyon side of White Rock Point. The bedrock at Georgia Hill has an elevation of 2,320 feet (2,340 feet, according to Goodyear), and the section illustrated in figure 16 is shown.

At White Rock Point there is andesite gravel above 30 to 40 feet of rhyolite tuff and thin gravel and the deposit forms a bench 25 to 90 feet above the Georgia Hill deep channel. Having swung around White Rock Point the channel crosses White Rock Canyon and enters squarely into the lava hill southwest of the canyon. The elevation of the bottom of the channel is 2,218 feet.

The deep channel is 30 feet wide and forms a narrow trough with 12 feet of quartz gravel mixed with rhyolite bowlders. Two benches 40 feet high, with a few feet of quartz gravel, have been mined on both sides of the deep channel, and a third 100 feet higher is said also to have been mined on the east side. The benches are probably earlier than the deep channel. Both are covered by rhyolite. Probably there was a covering of rhyolite on the 40-foot bench before the deep channel was cut and the whole trough filled with rhyolite.

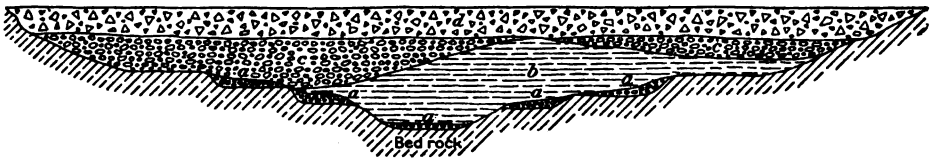


FIGURE 16.—Diagram of deposits in the Deep Blue lead, Placerville. *a*, Bench gravels and deep gravels of the interrhyolitic epoch; *b*, rhyolitic tuff; *c*, andesite gravel; *d*, andesite tuff-breccia.

From this locality on the Deep Blue has been mined all along to Smith's Flat except for one short interval of less than a quarter of a mile south of the Gas Pipe claim, but details are not obtainable. The course on figure 13 (p. 173) was indicated by Mr. Kimble, and it practically agrees with Goodyear's data. Some of the benches have been very rich. Those of the Live Oak and Roanoke claims are said to have yielded $19 a carload by drifting.

ANDESITE CHANNEL.

From Negro Hill a channel has been drifted through to Buell Hill, about one-fourth of a mile northward. The bedrock elevation is 2,146 feet (Goodyear). Close by the inlet on the north side of the Negro Hill ridge is a considerable pit called the Hancock & Salter claim, where a considerable amount of andesite gravel is exposed. Mr. Kimble asserts that an andesite channel runs through from this point to the east side of the Gas Pipe claim, where, as noted above, there is much andesite gravel. It is stated that this andesite channel was drifted throughout in a southwest direction and was 40 feet wide. It ran at an angle with the older rhyolite channels, planing off the top of the old bedrock ridge dividing the Negro Hill channel from the Deep Blue.

DEEP BLUE LEAD AT SMITHS FLAT AND PROSPECT FLAT.

At Smiths Flat the channel has been mined by a shaft 90 feet deep. The surface elevation at Smiths Flat is 2,239 feet, while the deepest channel lies at 2,149 feet. Important work was in Progress at Prospect Flat when Goodyear visited Placerville in 1871.

The Lyon mine is situated on Prospect Flat, a semicircular valley near Smiths Flat, surrounded by bluffs of rhyolite and andesite. The elevation of the collar of the old Robinson shaft is 2,214 feet (Goodyear). The bottom of the channel has an elevation of 2,114 feet. Goodyear says that the pay gravel was 13 feet thick and covered by "white lava." The deep channel is 100 feet wide, and the benches as wide or wider. Both deep channel and winding benches, as outlined on figure 13, were mined here. The total yield was $1,400,000. There are three benches 20, 64, and 90 feet above the deep channel. Between Bendfeldt's incline and the Robinson mine the Deep Blue lead has not been worked, but probably extends from the incline up to Smiths Flat. The exact level of the bottom of Bendfeldt's incline is not obtainable. It is situated about one-fourth mile southeast of Smiths Flat, at the big water wheel, and was 700 feet long; the channel was worked for some few hundred feet southwest.

LINDEN MINE.

The next point where the channel has been worked is at the Linden tunnel, one-fourth mile above the Cedar Spring tunnel, at an elevation of 2,028 feet. The tunnel first goes through the high rim of bedrock separating the Linden from the Green Mountain channel. Bending

eastward, it then cuts across the deep channel, which was 10 feet below tunnel level, the elevation of the deepest bedrock being about 2,028 feet. The tunnel then turns northeast and rises on a bench which has an elevation of about 2,075 feet, near end of tunnel. Most of the mining is done on these benches 15 to 20 feet above the bottom channel. At the most northerly workings the deep channel was again crossed and had an elevation of 2,053 feet, or 5 to 12 feet below the lower tunnel level.

The Linden bench gravel was about 5 feet deep. It averaged $2 a carload of 1,800 pounds, or $3.25 a cubic yard, and the total output from 1882 to 1894 was $130,000. Above the gravel rested rhyolite tuff. From Linden to the Lyon ground neither channel nor benches had been worked in 1901 for probably 1 mile along its course. The course from the Linden mine southward is much in doubt, but the channel must emerge at some place along the front of Webber Hill. It does not join the Green Mountain channel, for there is high bedrock below the lava on the east side of this channel. During the last few years this part has been drifted with good results from the Landaker mine.

SOUTH FRONT FROM WEBBER HILL TO TRY AGAIN.

At Webber Hill the bedrock elevations are lower than at any other place in the district, and the proximity of the deep Webber Creek channel is indicated.

Near the Epley quartz mine the bedrock on the ridge south of Chile Ravine is pretty high, but toward the east it sinks rapidly. At a tunnel on Landaker ground the bedrock elevation is 1,928 feet. One-eighth of a mile farther west rhyolite comes down on the bedrock, which is covered with a little gravel at an elevation of 1,898 feet—probably the lowest bedrock in the district. About 1,000 feet east of the Landaker tunnel the elevation is 1,935 feet and here 30 feet of gravel, mainly metamorphic, is covered by rhyolite and several acres of it has been washed.

ANDESITE CHANNEL, WEBBER HILL.

At the Landaker tunnel, at an elevation of 1,928 feet, heavy volcanic and metamorphic gravel rests on bedrock. It is cemented and contains some gold. This is, according to Mr. Kimble, a part of a late andesite channel, deeply cut in rhyolite almost to the depth of the deepest bedrock, and it is said to skirt the front of Webber Hill. The channel is broad, and bedrock rises in low benches above it. From the Landaker tunnel the bedrock continues low all along the front of the slope up to the Rivera tunnel, from the Great Eastern to the Gignac claim. It is covered by gravel containing rhyolite bowlders, above which rests rhyolite tuff 100 feet or more in thickness. Practically the whole face has been more or less extensively hydraulicked.

RIVERA TUNNEL.

The portal of the Rivera tunnel, owned by Chapman & Parker, has an elevation of 2,000 feet. The tunnel is on Rivera ground and runs N. 23° W., bedrock being about at tunnel level. The small hydraulic cut at the mouth shows 10 to 15 feet of coarse, hard cemented metamorphic gravel, covered with rhyolite and containing many bowlders of white lava. The tunnel continues for 900 feet on nearly level bedrock, then the bedrock rises sharply 50 feet; a drift continues from a corresponding raise 500 feet farther and encounters another sharp bluff, 60 feet high; a drift from a second raise continues 150 feet in gravel from this point. The bedrock in this second bench is 2,110 feet in elevation. The gravel is coarse and is similar to the bottom gravel, but contains small streaks of sand and some quartz. The values were rather low as far as the early exploration in 1901 was carried. We have here clearly broad benches of the rhyolitic period swinging northward from the main stream of Webber Creek.

CLARK TUNNEL.

A short distance below Parker's house is the Clark tunnel, at an elevation of 2,070 feet. This tunnel starts above bedrock and continues northward for several hundred feet, meeting a first small bench containing bowlders of white lava. A second bench was found 65 feet above

and carried heavy wash without volcanic bowlders. It contained fine quartz gold and was fairly rich. This is the highest bench known and is supposed to belong to the Linden channel, or to lie on the bedrock divide between that and the Big Webber Creek channel.

DITCH CO. TUNNEL.

The Ditch Co. tunnel is located 100 feet higher than the Rivera and 1,200 feet northeast of it, at an elevation of 2,100 feet, just above the road, in bedrock. Rhyolite and rhyolitic gravel are seen near it and the bedrock rises eastward. The tunnel was driven to reach a bench worked by the Ditch Co. long ago from a 179-foot shaft on ditch level. This bench, which yielded good returns, had an elevation of about 2,150 feet and probably corresponded to the high Clark bench farther down.

The tunnel was run about 1,500 feet, but failed to find anything of importance. A high bench of the Lyon ground is said to have been worked right up to the Ditch Co.'s ground. This seems to indicate the flat, partly gravel-covered divide between the Smiths Flat channel and the Webber Creek stream.

TRY AGAIN TUNNEL.

From the Texas Hill tunnel the bedrock continues pretty low for half a mile, but then rises rapidly to a maximum elevation of 2,220 feet. The Try Again tunnel is in bedrock at an elevation of 2,186 feet. There is probably some rhyolite right along the contact from the Texas Hill tunnel to Try Again, though exposures are not very good.

A short distance east of the Try Again tunnel the bedrock sinks almost to tunnel level, and a small hydraulic cut has exposed about 50 feet of gravel with a few rhyolite pebbles. This work was done in 1897, but paid poorly, it is reported, and only $1,000 was obtained from the cut.

Immediately northeast of this point the bedrock rises considerably. The Columbia tunnel was run here long ago, but did not break through the rim. This is a little higher than Try Again. High bedrock continues to a point near the Toll House at Smiths Flat.

At Try Again a 2,000-foot tunnel has been run to the north-northwest, striking good pay 1,000 feet in and then following a channel for 1,000 feet north-northwest, probably draining northward. At the Kum Fa incline, sunk at the elevation of the ditch, on the north side of the ridge, the bedrock, it is stated, was 80 feet deeper than at the end of the Try Again tunnel, which would make the elevation of the bedrock at the bottom of the incline about 2,100 feet, allowing for tunnel grade.

This indicates a small tributary draining toward the Deep Blue channel. It is held by many that the main deep channel of the Tertiary American River entered here and connected with the Deep Blue at some place underneath the lava. This is altogether improbable, and in fact is directly contradicted by the small amount of gravel and rhyolitic tuff present at this locality.

CONCLUSIONS.

The Deep Blue lead is a tributary to the main Tertiary American River. Its general course is first from north-northwest to south-southeast for 2 miles, from White Rock to a point near Smiths Flat. Practically the whole of this stretch has been drifted, except for a quarter of a mile south of the Gas Pipe claim. From Smiths Flat to the outlet near the Landaker tunnel the channel's general course is from east-northeast to west-southwest for 2 miles. This portion has been opened by the Lyon and Linden mines, but in 1901 about 1 mile remained on each side of the Linden workings. Both of these remaining parts are now reported to be worked. The lead consists of a deep, fairly straight channel flanked by broad, swinging and curving benches older than the deep channel. All of these gravels belong to the interrhyolitic period. Apparently none of the bench gravels were deposited before the beginning of the rhyolitic flows, for cobbles of rhyolite tuff are contained in all of them. All the gravels are

covered by a thick sheet of this tuff. The total yield from drifting operations amounts to several million dollars.

The grade from White Rock to Prospect Flat is 39 feet to the mile, the direction being nearly north-south and the distance 3 miles. From Prospect Flat to the Linden mine the grade is 53 feet to the mile, the direction being southwest and the distance 1⅜ miles. The benches had throughout a lesser grade than the deep channel. According to Mr. Kimble they were almost level in places in the Green Mountain channel. Mr. Kimble's data do not agree entirely with the figures from the grades stated above. He gives for the Deep Blue from the Gas Pipe claim to Smiths Flat 53 feet to the mile and for the Green Mountain channel 98 feet to the mile.

The elevations given are summarized below:

Deep channel elevations at Placerville.

	Feet.
Georgia Hill	2,320 (2,340 Goodyear).
White Rock	2,218 (2,243 Goodyear).
Smiths Flat	2,149
Prospect Flat	2,100 (2,114 Goodyear).
Linden mine (west side of claim)	2,028
Green Mountain, north end	2,010
Green Mountain, south end, at Kimble's tunnel	1,948–1,931
Deepest bedrock, Texas Hill	2,000
Deepest bedrock, Webber Hill	1,898
Deepest bedrock, Excelsior	1,985
Try Again tunnel	2,150

GRIZZLY FLAT AND FAIR PLAY.

In taking up the southeast corner of the quadrangle we leave the basin of the Tertiary American River and enter that of the Tertiary Mokelumne, the intervening stream, the Cosumnes having no Tertiary representative. The headwaters of the western branch of the Tertiary Mokelumne River were south of Baltic Peak, a rough slate ridge, which, rising abruptly about 1,000 feet above the stream beds, separated this basin from that of the American. This stream flowed south-southwestward and its deposits underlie the andesitic tuff area of Grizzly Flat, where its valley is 500 feet deep and about 6,000 feet wide. The gravel deposits are thin and narrow; the inlet is located 1¼ miles north-northeast of Grizzly Flat, above the Melton mine. The rim of the channel is again visible in a gulch three-fourths of a mile north of the town, and finally a short distance northeast of the town. Hydraulic work and drifting have been carried on at several places.

The channel appears again at Henry Diggings, 3 miles farther south, underneath a small andesite area on a ridge 800 feet above the Cosumnes, the interval having been eroded by Steeley Fork. The gravels of Henry Diggings are reported to have been rich. The elevation of Grizzly Flat being taken as 3,750 feet and of Henry Diggings as 3,550 feet, the grade would be about 60 feet to the mile.

South of the Middle Fork of the Cosumnes the channel enters the Brownsville or Mendon Ridge probably at a point about due south of Henry Diggings. The connections are not established with certainty, but it is probable that the channel continues southward, crossing Cedar Creek about half a mile west of Mendon at an elevation of 3,000 feet and the South Fork of Cedar Creek at the Leventon incline, 1 mile north of Indian Diggings, at an elevation of 3,050 feet. This incline is 280 feet long at an angle of 15° and failed to reach the bottom of the channel, the deepest point attained having an elevation of 2,985 feet; a heavy flow of water stopped operations. A bench of quartzose and metamorphic gravel was found; some of the slate bowlders were very large and smoothly washed. On the assumption that the distance is 4 miles from Henry Diggings, the grade would be 144 feet to the mile. The general direction of the stream seems to have turned westward south of Cedar Creek and the outlet was probably near Boughman's old sawmill, 2 miles west of the Leventon incline. Possibly

there is also a channel underneath the lava ridge north of Cedar Creek. The general direction from this locality seems to have been southwestward along Cedar Creek, and the channel beyond the interval eroded by the present South Fork of Cosumnes River probably entered the lava ridge 3 miles east-northeast of Oleta, where the bedrock elevation is 2,200 feet. Assuming a distance of 10 miles from the Leventon incline would give an average grade of 77 feet to the mile. Rhyolite appears in the deepest part of the channel near Oleta and the bedrock relations show that the Tertiary stream crossed over into the Jackson quadrangle.

A gravel deposit covered by rhyolite tuff and probably belonging to this stream caps the top of the ridge between Cedar Creek and Flat Creek 2 miles east-southeast of Mount Orcum, at an elevation of 2,450 feet.

There remain to mention three points of importance, which, however, are not located on the principal Tertiary streams. At these three points rock gravels covered outcrops of limestones of the Calaveras formation and were found in those irregular and deep potholes which so frequently occur on limestone bedrock. The first of these places is at Slug Gulch, 2 miles east of Fair Play. A channel appears to traverse the narrow lava-capped ridge and its continuation is probably found toward Fair Play. Hydraulic operations have been carried on here for many years and production is still maintained. The gold is very coarse. The diggings at Mendon or Brownsville, 4 miles farther east-southeast on the same ridge, appear to be exhausted. The third locality, at Indian Diggings, 6 miles east-southeast of Fair Play, has been extremely productive, and even now an annual output of \$7,000 to \$10,000 is maintained from drifting and sluicing. The bedrock here is a wide belt of limestone striking east and west; it is decomposed to great depth and contains numerous rich potholes. The elevation of the bedrock is 3,200 feet, which shows that the locality is not on the main channel disclosed by the workings of the Leventon incline, 1 mile to the north.

Gravels of various ages are present in the Fair Play region; there are evidently older benches of prevolcanic quartzose gravel and deeper incised intervolcanic stream courses. The investigation has not been detailed enough to describe these channels in detail. Many of the older benches are rich, but it seems as if in the younger channels the accumulation of gold had not proceeded long enough to form valuable deposits.

CHAPTER 16. THE PYRAMID PEAK QUADRANGLE.

GENERAL GEOLOGY.

The Pyramid Peak quadrangle, which adjoins the Placerville quadrangle on the east, comprises about 1,000 square miles of the summit region of the Sierra. It includes the eastern part of the main block of the Sierra Nevada, the crest line of which lies just west of Lake Tahoe and reaches an elevation of a little over 10,000 feet. On the whole the surface of the block slopes evenly toward the west, unbroken by faults or deformation.

Granitic rocks, which are described in detail in the Pyramid Peak folio,[1] occupy the largest part of the area. Along the eastern boundary line the granitic rocks adjoin, with irregular intrusive boundary line, the Carboniferous Calaveras formation. A few small isolated areas of sedimentary rocks and greenstones, probably of Triassic age, lie in the granites of the northeastern part of the quadrangle. Tertiary volcanic rocks cap most of the ridges to the south of South Fork of American River.

The fault line along the western shore of Lake Tahoe bounds the main block of the Sierra on the east but appears to die out a few miles south of Fallen Leaf Lake. A few miles to the east the fault along the east side of Lake Tahoe likewise dies out, and south of this the western block continues unbroken across into the Markleeville quadrangle, where it is bounded on the east by the Carson fault.

GOLD-BEARING AREAS AND PRODUCTION.

The quadrangle is outside of the gold belt except for a narrow strip along the western boundary line. The gold-bearing area practically covers the extent of the Calaveras formation, and creeks and rivers become barren as soon as they pass from this formation into the granite. Few quartz veins are, however, contained in these slates, and the watercourses have generally been poor in gold. The total production is small.

TERTIARY GRAVELS.

The prevolcanic gravels which lie upon the old bedrock surface of the range, such as it was before being flooded by lava and trenched by the modern canyons, are not represented in this quadrangle. The rivers deposited scarcely any débris in the upper part of the range near their headwaters. The Tertiary gravels occur only along the western boundary of the quadrangle, and generally in very small exposures. They are interbedded with rhyolitic tuffs, and are found only in the bottom of the old depressions.

In the southwestern part of the quadrangle the gravels contain gold and have been worked in many places. The main channel of the Tertiary South Fork, coming down from the vicinity of Round Top, passed by the sites of Morrison, Ditch Camp 7, and Bullion Bend. The first gravels are seen at Ditch Camp 7, where a small patch, about 8 feet thick, has been hydraulicked with satisfactory results. On the hill northwest of Bullion Bend, 600 feet above the present river, are several small patches of gravel, with a maximum depth of 40 feet, containing rhyolite pebbles. These have been washed with good success, and some gravel still remains. A deeper postrhyolitic channel, though less rich, has been worked under the lava 1 mile eastward.

The rest of the Tertiary gravels in the quadrangle are found along the tributary joining the old Mokelumne River at Fort Grizzly, and extending, with a general north-south direction, up toward an old divide north of Camp Creek, Cosumnes River not being represented in the Tertiary drainage system. The shallow gravels under the lava have been worked at and west

[1] Pyramid Peak folio (No. 31), Geol. Atlas U. S., U. S. Geol. Survey, 1896.

of Van Horn Creek, a tributary to the North Fork of the Cosumnes; near the head of Steeley Fork, where some hydraulic work has been done, and 1 mile east of Dogtown, where the channel crosses the two branches of the North Fork of the Middle Fork of Cosumnes River. Here a few feet of gravel resting on granitic bedrock is covered by rhyolitic tuffs, and considerable work has been done by means of sluicing and hydraulicking, the banks reaching a height of about 30 feet at Candell's and Estee's claims. The ground is said to have been very rich in places. The channel continues southward to Mayer, and is there indicated by rhyolitic tuffs covering gravels of slight thickness. At this point the gravels are very profitably washed on a small scale. Four miles west of Mayer, on the same ridge, is another and smaller channel, on which some work has been done at the head of the rich Russian Ravine and at Acksley's claim, half a mile northeast of Lane's tunnel. The gravel is shallow and covered by a white tuff. Quartz pebbles are common here, as in the other channels. Lane's tunnel was driven 900 feet under the lava in order to find this channel, but is said to have been located at too high an elevation. South of Mayer, across the Middle Fork of the Cosumnes, a little hydraulic work has been done on the same channel. Farther southwest small hydraulic cuts indicate where the higher or rhyolitic channel crosses Sopiago Creek. A lower postrhyolitic channel crosses the same creek at Barneys. At Fort Grizzly this important tributary joined the old Mokelumne River. A great deal of placer mining has been done in this locality, and a little is still in progress. The rhyolite attains a maximum thickness of 300 feet, and at Fort Grizzly goes down to the level of the creek, so that it is not probable that the very bottom of the Mokelumne channel is exposed. There is a considerable quantity of partly washed quartz and metamorphic pebbles, but the actual thickness of gravel below the rhyolite is probably not great.

QUATERNARY GRAVELS.

The Quaternary gravels in the whole northeastern part of the quadrangle are practically barren, though in some streams scattered colors may be found. In the southwestern part the gravels in some places are rich enough to be worked, though poor compared to the deposits farther down on the slope of the Sierra. The workable deposits, as a rule, begin to appear along the eastern edge of the Calaveras formation, though some are found on the adjoining granite and diorite. Some placer gold is found on Little Silver Creek, in the Calaveras formation; a little occurs also on the South Fork of American River, at the western boundary of the quadrangle; and the different branches of the Cosumnes have been worked with some profit at several places along the western border. One of the richest gulch deposits was found at Russian Ravine, a small tributary from the north to the Middle Fork of the Cosumnes, 3 miles west of Morgan, from which, it is said, gold to the value of $50,000 was extracted. The various tributaries to Mokelumne River along the southern margin of the quadrangle are practically barren. Some fine gold occurs in the gravels of Silver Fork, north of Hells Delight Valley, but scarcely in workable quantities. Some rich placer ground is said to have been found long ago in a gulch about a mile southwest of Mokelumne Peak.

RHYOLITE.

The rhyolite is confined almost entirely to the southern part of the quadrangle and occupies only a relatively few square miles. A flow of rhyolite once filled the bottom of the Tertiary valley of American River, the lower Mokelumne and its Dogtown tributary, but is now partly eroded and partly covered by andesite. The places of eruption of this acidic lava were located without doubt in the eastern portion of the quadrangle. The principal flow can be traced to the high volcanic complex about 4 miles south of Echo. Flowing down a steep tributary, it found the main Tertiary river near the present bend of Silver Fork, and followed it down by Morrisons and Plum Creek. A small flow of this lava followed the Dogtown tributary by Pi Pi Valley and Sopiago Creek to the larger areas at Fort Grizzly. Whence this flow and that of the Dogtown tributary came is uncertain; possibly a local eruption took place in this vicinity, for between Fort Grizzly and Silver Lake no trace of the rock is found.

Before the andesitic eruption the surface of the rhyolite suffered considerable erosion, so that its thickness differs much in different places. The heaviest masses are not found near the place of eruption, but near the western boundary of the quadrangle. A maximum thickness of 400 feet is found on Plum Creek, but ordinarily the thickness does not exceed 300 feet and locally it is much less. A tendency to form steep bluffs distinguishes the rock in many places. It is commonly massive, tuffs occurring only near the western boundary of the quadrangle. The normal rhyolite is a white, gray, or pink fine-grained rock, somewhat porous and easily dressed with the hammer.

ANDESITE.

The andesitic flows were the latest of the Neocene series of eruptions and cover large areas in the southern part and the northwest corner of the quadrangle; the northeastern part is remarkably free from them. In general, the andesitic rocks now form the tops of the ridges, but the contact line with the underlying granitic or schistose series is far from being as regular and even as it is at many places lower on the slope of the Sierra; indeed, proofs are everywhere abundant that the surface upon which the andesitic lavas flowed out was an irregular one of considerable relief. The present canyons, however, have been cut considerably below the Neocene surface, and during this process a great part, perhaps half, of the original volume of the lava flows has been removed. It is evident that the flows once covered continuously almost the whole southern half of this quadrangle, and that only a few higher bedrock points near Round Top, Mokelumne Peak, and possibly Leek Spring Hill projected above the volcanic plateau. On the other hand, it is also evident that the larger part of the northern, higher half has never been submerged in a similar manner. In many places in the deeper parts of the old channels the andesite rests on rhyolite, but over the larger part of the area it lies directly on granitic or schistose rocks. These appear, in the few good exposures, to be soft and crumbling, but no evidence of any notable accumulations of débris has ever been found except in some of the channels, as stated above. The thickness of the flows is considerable. In the northwest corner of the quadrangle it reaches 1,000 feet; in the southwestern part it ranges from a few hundred up to 1,000 feet along the deeper drainage channels. The greatest thickness is found on the northeast side of Silver Lake, where it reaches 2,000 feet.

In the eastern glaciated part the exposures are very much better; in numberless places the beautifully bedded appearance resulting from the superimposing of numerous flows of slightly differing structure is brought out. These long slopes, of a somber dark-gray or reddish-gray color, covered by scanty herbage or scattered trees, alternate with precipitous walls strongly resembling fortifications with scarps, parapets, and buttresses. In places where erosion has carried its work still further, as in the vicinity of Thimble Peak, peaks and pinnacles of the most fantastic form result.

The andesitic flows consist almost entirely of tuffs and tuffaceous breccias in an indefinite number of sheets, differing in hardness as well as in size and abundance of the andesite bowlders, which range up to several feet in diameter. They all consist of angular andesite fragments bound in a cement of finer andesitic detritus; very little nonandesitic material is present, though granitic bowlders may occur here and there. The andesite is a dark, rough, and porous rock, containing porphyritic crystals of plagioclase and almost invariably pyroxene, principally augite but also hypersthene; hornblende is less abundant, but also common; the groundmass varies from microcrystalline to glassy. Flows of massive andesite occur rarely, but in many places near the volcanic centers the tuffs and breccias contain necks of massive hornblende andesite, as on Old Round Top, north of Twin Lakes.

TERTIARY TOPOGRAPHY.

As there are, within this region, no evidences of Neocene or post-Neocene faulting, nor evidences which would lead to the belief that any strongly marked deformations of the surface have occurred, it follows that a study of the numerous contact lines of the Neocene eruptive rocks with the underlying "Bedrock series" may give a correct idea of the detailed topography

of the surface on which these flows were spread. Over a large portion of the region it would, indeed, be feasible to reconstruct the Tertiary surface and indicate the relief by contour lines.

In general the Tertiary surface of this quadrangle was characterized by broad high plateaus and level-crested ridges. The rivers flowed in sharply defined valleys with steep slopes, not quite so abrupt, however, as in the modern canyons.

North of American River extended a wide granitic plateau. This region has not been covered by andesite, and its present drainage is not very different from that of Tertiary time. Then as now the flat ridges of Robbs Peak rose above it on the west, while on the east it was bordered by the lofty summits of the Pyramid Peak Range (see Pl. XIX, *A*, p. 134), rising about 3,000 feet above it. The Pyramid Peak Range is continued northward beyond the limits of this quadrangle by McKinstry Peak, Snow Mountain, English Mountain, Sierra Buttes, and the Grizzly Mountains. It is a very old divide of the early Tertiary or pre-Tertiary representative of the Sierra Nevada. South of Pyramid Peak this old divide can not be definitely traced. It is probable that its level-crested summits, as well as those of Robbs Peak, form the remnants of a very old, probably Cretaceous, topographic surface.

South of American River the main granitic plateau extended to the southern and eastern boundaries of the quadrangle, except where trenched by the Tertiary equivalent of Silver Fork and the Mokelumne, and it attains a present elevation of over 9,000 feet near Round Top. Local eminences or monadnocks rise from 500 to 1,000 feet above it, the most conspicuous being Mokelumne Peak, in the southeast corner of the quadrangle.

We have then, first, a probably Cretaceous surface represented by the highest eminences; and, second, a Cretaceous or early Tertiary surface or approximate peneplain. The latter is distinctly and deeply trenched by probably Eocene canyons, excavated before the deposition of any of the gravels on the lower slope.

The Tertiary American River followed almost exactly the course of the present canyon of South Fork up to its very head, trenching the plateau from east to west. The present canyon is from 2,000 to 2,500 feet deep. The Tertiary canyon had cut down within 500 feet of this depth. In other words, the present canyon has simply been evenly deepened 500 feet throughout its course from the western boundary line of the quadrangle to a point near Phillips, 5 miles from its eastern line.

The canyon of the present South Fork is suddenly cut off at Johnsons Pass, near Audrain Lake, by the deep and narrow trench of the Upper Truckee, draining northward into Lake Tahoe, and the river has no normal headwaters. The andesite occurring in the canyon of the upper South Fork proves that it existed practically in its present form before the andesitic eruptions. From this peculiar wind gap of Johnsons Pass (elevation 7,400 feet) another entirely similar wind gap, 1,500 feet deep, lying to the southeast, may be perceived across the Little Truckee Canyon. This is Luthers Pass (elevation 7,700 feet), leading over into Hope Valley (in the Markleeville quadrangle), and the basin of Carson River. No other explanation of these facts appears possible than that the South Fork of the American formerly rose in Hope Valley, that Carson River has captured the headwaters, and that the Upper Truckee has cut the canyon in two. As it is known that Hope Valley was a few hundred feet lower than Luthers Pass at the time of the andesite flows, it may be concluded that these events happened before the beginning of the volcanic eruptions.

The other branch of the Tertiary American River headed, as noted above, near Round Top, and its headwaters were of a normal character. Near the western boundary of the quadrangle it was separated from the tributaries of the Mokelumne by a comparatively low divide, but its canyon deepened rapidly eastward and is well exposed by Alder Creek, cutting across the channel at Morrison. A narrow ridge 1,500 feet high separated this branch from the northerly fork, just described. Southward the slopes also rose rapidly 1,500 feet to the rolling, high granitic plateau culminating in Leek Spring Hill. East of this plateau the topography gradually grew more rugged, and the character of the broad shoulders of granodiorite separated by deep canyons is very clearly indicated by the contact lines.

The basin of the Tertiary Mokelumne River in this region coincides, roughly speaking, with its present basin, but also takes in the headwaters of the present Cosumnes. The old channel of the Mokelumne is exposed near Fort Grizzly, whence it continues southwest below the andesite ridge into the Jackson quadrangle. It can be traced upward, crossing Tiger Creek at Tarrs Saw Mill and Panther Creek near Dutch Henry. It probably crossed the southern boundary near Westmoreland, and is again found in the Big Trees quadrangle south of the present river.

South of this channel line the andesite contact rises several hundred feet, but the great Mokelumne Canyon has eroded the larger part of the Neocene valley slope. Northeast of Dutch Henry the Tertiary surface rose 1,700 feet in 2 miles, to the level of the plateau of Leek Spring Hill. The modern canyon of the Mokelumne is in this vicinity no less than 1,200 feet below the Neocene river.

An important tributary, which will be referred to as Dogtown Creek, joined the Mokelumne at Fort Grizzly and extended northward to Camp Creek. With its several branches it occupies the rather wide Neocene valley lying between the Leek Spring Hill plateau and another high plateau in the adjoining Placerville quadrangle of which Baltic Peak is the remnant, rising to an elevation of 5,100 feet.

Along the main Tertiary valleys of the American and the Mokelumne there is evidence of the existence of two channels, the later one being eroded in the interval between the rhyolitic and the andesitic flows. This intervolcanic erosion produced an irregular surface of the rhyolite, and in many places the new channel cut through the rhyolite and trenched the bedrock surface below that rock. This is shown near the bend of Silver Fork, northwest of Bullion Bend, near Morgan, and on Sopiago Creek, while along Plum Creek it is evident that the rhyolite flows, which here are very deep, had not been cut through. Nowhere does the later channel lie more than 100 feet below the earlier one, and the general character of the surface was not affected by this erosion.

GRADES OF THE TERTIARY STREAMS.

The Tertiary American River, as explained above, followed closely the present canyon of the South Fork, from Bullion Bend (elevation 3,600 feet) to Johnsons Pass (elevation 7,500 feet). In a distance of about 28 miles, following the probable river curves of the old stream, there is a grade of 139 feet to the mile. The grade of the lower half varies from 100 to 133 feet to the mile; the upper part, from Georgetwon Junction to Johnsons Pass, had a grade of 160 feet to the mile. The direction of the river is throughout a few degrees south of west. From Johnsons Pass to Luthers Pass the direction of the former channel is northwest and the grade is only 50 feet to the mile, which seems to indicate that the fault lines on each side of Lake Tahoe have not appreciably disturbed the rocks 10 miles south of it.

The grade of the tributary which joined the main river at Bullion Bend and headed near Round Top is 160 feet to the mile, the direction being a few degrees north of west, but the grade increases rapidly from 170 feet to the mile in its lower course to 220 feet to the mile near the headwaters, a short distance north of Round Top.

The tributary to the Tertiary Mokelumne River which joined it near Fort Grizzly after a southward course of about 12 miles has a grade of only about 100 feet to the mile.

CHAPTER 17. THE MARKLEEVILLE QUADRANGLE.

GENERAL GEOLOGY.

The Markleeville quadrangle adjoins the Pyramid Peak quadrangle on the east. The California-Nevada State line passes through it diagonally from Lake Tahoe on the northwest to Antelope Valley on the southeast. In California the area comprises small parts of Eldorado and Mono counties and the larger part of Alpine County. The Nevada portion lies in Douglas County. No geologic map of this quadrangle has been issued, but the main features are known from reconnaissance work by H. W. Turner in earlier years and by the writer and H. C. Hoover in 1895. (See Pl. I, in pocket.) The southwestern part includes the eastern slope of the Sierra Nevada; along the eastern boundary extends the first of the ranges of the Great Basin, the Pine Nut Mountains, separated from the Sierra by a low pass. North of this pass, at an elevation of 5,000 feet, lies the broad and flat Carson Valley, reaching from the gentle slope of the Pine Nut Mountains on the east to the abrupt scarp of the Sierra south of Carson. South of the pass opens the Antelope Valley, drained by West Walker River, which in the extreme southeast corner of the quadrangle hugs another steep escarpment of the great range. The highest points of the Sierra, in this quadrangle, fall a little short of 11,000 feet in elevation.

The western part of the quadrangle is essentially a high, glaciated ridge of granite and granodiorite, beginning on the north in the narrow buttress rising between Lake Tahoe and Carson Valley. Along the southern edge of the quadrangle granitic rocks reach across to West Walker River and form the steep escarpment west of Antelope Valley. Most of the rock is granodiorite. North of Hope Valley, extending up to Jobs Peak, the granodiorite is replaced by a normal quartz monzonite or granite similar to that which in the quadrangle to the west forms the conspicuous Pyramid Peak range. Almost everywhere the granitic rocks are jointed and fissured, in strong contrast to conditions farther down on the west slope. This jointing is especially developed in Charity Valley (Pl. VII, *B*, p. 32); in Summit Creek, southeast of Round Top, and in the West Carson Canyon. The most prominent joints strike north or north-northwest and dip from 40° to 80° east or west. At the Blue Lakes and Indian Valley the direction is east and west.

A few small bodies of metamorphosed sedimentary rocks are embedded in the granite or granodiorite and have suffered much change from both regional and contact metamorphism. All of them present characteristics suggesting identity with the Triassic and Jurassic rocks appearing near the granite contact in the Pyramid Peak and Truckee quadrangles. One of these areas near Stevens Peak is conspicuous by the bright-red color of the outcrops and consists of black clay slates, quartzitic schists, and some limestone. The schist near Fredericksburg, at the mouth of the West Carson Canyon, is composed largely of amphibolite. A somewhat larger area of metamorphic rocks is exposed at the northern edge of the quadrangle from the Hot Springs to Genoa. The rocks are in part amphibolitic greenstones, but siliceous slates and clay slates are also present and dip west at moderate angles. The schist areas in the Pine Nut Mountains which, south of the Mountain House, extend up to the State line are somewhat different and consist chiefly of light-gray slates, in places altered to knotty schists. Highly pressed conglomerates with flat pebbles are also present. The areas exposed are not large.

The volcanic rocks which cover the larger part of the quadrangle are divisible into two distinct series. The first comprises the main area of volcanic rocks in the center of the quadrangle with scattered patches resting on the uneven granite surface of the western part of the quadrangle. These rocks are identical with the andesitic flows and tuffs that cover so large

a part of the western slope of the Sierra. Their period of eruption falls in the latest part of the Tertiary. The rocks are little altered by static metamorphism and their rough dark-brown outcrops are very characteristic. Both hornblende andesites and pryoxene andesites are present and minor areas of rhyolite and basalt are also found. The andesites are largely breccias, in places tuffaceous, but generally not so plainly stratified as the tuffs of the western slope. Necks and masses of solid andesite penetrate the breccias at many points, and it seems likely that the points of eruption for a large part of the flows of the western slope were located in this vicinity. The thickness of the andesitic masses is very considerable; near Silver Mountain a section between 3,000 and 4,000 feet thick is exposed.

Igneous rocks of a different class are exposed in the Pine Nut Mountains. There is a small area of granite at the summit about 8 miles northeast of Mountain House and small areas of diorite near the north end of the range, but with these exceptions the Pine Nut Mountains consist chiefly of porphyritic rocks of a great variety, but showing throughout the characters of surface flows. Hornblende andesites, pyroxene andesites, light-colored rhyolitic rocks, and some diabase breccia are all represented. The outcrops form yellowish-brown, rather smooth hills, contrasting strongly with the rough reddish outcrops of the andesites of the Sierra. The rocks of the Pine Nut Mountains are throughout somewhat altered by chloritization and present unquestionably an older aspect than the andesites, which, moreover, near the Mountain House distinctly overlie them. The Pine Nut Mountains are continued northward by the Virginia Range and at least a large part of the igneous rocks of that range are probably older than the andesites of the Sierra Nevada.

The higher region of the western part of the quadrangle was covered by glaciers in Quaternary time, but they mainly extended toward the west and probably in no place reached the level of Carson Valley.

STRUCTURAL FEATURES.

At least three main dislocations of the fault system of the eastern slope traverse the Markleeville quadrangle. Along the southern boundary line the main granite mass of the Sierra extends across the quadrangle to Antelope Valley, where a steep eastward-facing escarpment marks the most southerly of the fault lines. This steep escarpment, from 3,000 to 4,000 feet in height, continues in a north-northwesterly direction, with gradually decreasing height, as far north as Mountain House, where the Pine Nut Range may be said to begin. The relation of this part of the Pine Nut Mountains to the scarp is not quite clear.

The second fault line extends from the vicinity of Silver Mountain and Grovers Springs to the mouth of West Carson Canyon and northward to Genoa and Carson. The escarpment marking this line attains its greatest height at Monument Peak, where an unbroken slope of 5,200 feet in 3½ miles descends to the level of Carson Valley.

The third fault line is that following the western shore of Lake Tahoe; about 10 miles south of the lake this fault appears to bend to the west and join the dislocation on the west side of the lake.

It has been shown that the depression of Lake Tahoe already existed in the early part of Tertiary time.[1] This last-mentioned fault scarp, then, is of considerable antiquity and there is no evidence whatever that faulting, even on a small scale, has recurred along it in post-Tertiary time. The slopes are fairly steep and from 2,000 to 3,000 feet in height, but, unlike the eastern slope, the lower declivities are usually more gentle than the upper. West of Luthers Pass this fault has apparently died out entirely and farther south the main block of the Sierra continues unbroken until the Genoa fault line is reached.

In a similar manner the Genoa fault line dies out south of Markleeville and, as stated above, at the southern edge of the quadrangle the main block of the Sierra continues unbroken to the escarpment at Antelope Valley. South of West Carson Canyon the andesite lies piled up against the Genoa fault scarp and there is no indication that any postvolcanic movement has taken place along this part of the line. But from the vicinity of Woodfords northward the

[1] Truckee folio (No. 39), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

conditions change entirely. The escarpment increases in height and steepness. Carson River follows its eastern base closely and swampy meadows actually reach the very foot of the fault scarp. At least three successive dislocations have taken place along this fault line. Some movement has occurred within the last 50 years. From Walleys Hot Springs to Genoa the scarp rises with extreme abruptness and cloud-bursts have often carried enormous bowlders far out in the valley. The precipitous slopes are practically denuded of forests and more landslides may be expected. The slope is steepest close to the valley and gradually lessens with increasing height. This characteristic alone strongly suggests dislocation. A mile north of Genoa evidences of recent disturbance begin. At this place a débris fan is clearly faulted. At Walleys Hot Springs a distinct fault line at the foot of the escarpment can be traced for 2,000 feet, within which distance the small débris fans at the mouths of the gulches are faulted, the scarp being about 40 feet high. Between the little gullies the fault cuts the solid rock, which is extremely crushed; large blocks show slickensides and striated faces coated with quartz and calcite; seams of these minerals also traverse the granitic rock in all directions. Just at the face of the fault are several outcrops of a rusty-looking rock having the appearance of a fissure vein which has been deposited by the hot water along the fault plane before being exposed by this last dislocation. A shaft about 50 feet deep has been sunk here and the material is said to contain some gold.

An enormous amount of water issues as springs along this dislocation. One mile south of Sheridan probably 1,000 gallons a minute issues within a quarter of a mile at the very foot of the projecting shoulder of Jobs Peak; one of these springs is tepid. About 2 or 3 miles farther north are more exceptionally large springs and beyond this begins the line of Walleys Hot Springs, 2,000 feet long; these come out so continuously along this distance that the aggregate volume is probably large. The temperature at the hottest spring is 146° F. The water is rich in hydrogen sulphide, but contains so little of the dissolved salt that it can be used for irrigation. No spring deposits are formed. According to an analysis by J. Warren Phillips the hypothetical composition of the water is as follows:

Analysis of water at Walleys Hot Springs.

	Parts per million.
Sodium sulphate	212.808
Potassium sulphate	11.605
Calcium sulphate	37.602
Sodium hyposulphite	6.930
Sodium bicarbonate	11.065
Sodium borate	29.816
Sodium chloride	81.900
Silica	48.900
Alumina	.500
Ammonia	.035
Carbon dioxide	111.109
	552.270

The relation of the alluvium of Carson Valley and the escarpment is sufficient proof of a downthrow on the east side of the dislocation.

Other evidence tends to show that a dislocation had already taken place along this line in Cretaceous or early Tertiary time. In examining this question the general configuration of the Tertiary surface must be considered. The summits of the main granite ridges of the quadrangle show in places characteristic gentle slopes which break off abruptly into scarps of faulting or erosion. It is held that these gentle slopes represent the remnants of an old topography which far antedates the andesitic flows, the gravels, and probably the entire Tertiary period. At Luthers Pass a conspicuous wind gap is cut about 1,500 feet below the gentle slopes. This remarkable depression connects with a similar one across Little Truckee River, in the Pyramid Peak quadrangle, and the latter is clearly shown to have been the valley of the Tertiary American River. Where the upper headwaters of this stream, east of Luthers Pass, were situated it is impossible to say, for about 600 feet below it now extends the broad and gentle depression

of Hope Valley containing the headwaters of West Fork of Carson River. The inference is that owing to dislocations along the eastern base the West Carson, at some epoch long prior to the andesitic flows, captured the headwaters of American River and within the area occupied by them carved a depression several hundred feet below the old level of the American. The contact lines of andesite and granite show that at the time of the andesitic flows Hope Valley existed much in its present form. The river, now as then, traverses it in gentle meanders and its outlet at the time just prior to the andesitic flows was through West Carson Canyon, which then was less deep and had an even stream bed of moderate grade. In the canyon, flows of andesite now descend to an elevation of 7,200 feet, but not lower. The present character of the canyon and the relation of the andesite areas bear testimony to a recent rejuvenation of the powers of the stream and it is concluded that the postandesitic faulting at the mouth of the canyon amounted to about 2,000 feet. It is only a matter of time when the river will cut back farther and change the gentle slopes of the valley to abrupt canyon sides.

The Tertiary surface of the range in the western part of the Markleeville quadrangle presented a strongly accentuated topography, with broad, open valleys, above which the granitic ridges rose to heights of 3,000 and 4,000 feet. The details can not be traced out at all points, because this whole block has been greatly crushed by the stresses effecting the uplift of the Sierra and in many places within the block faulting parallel to that of the main scarp has taken place.

The two branches of Carson River, referred to as East Fork and West Fork, exhibit some striking differences which are due to the postvolcanic disturbances. The East Fork traverses from south to north the entire main volcanic area and, so far as can be seen, has not been affected by later faulting. This stream is throughout well graded and flows for the most part in an open valley lined with gravel terraces, the highest of which are about 100 feet above the river level. The terraces are probably due to recent sinking movements in Carson Valley.

The West Fork, on the other hand, crossed the escarpment in West Carson Canyon and at that place has so greatly increased its grade that it now forms a succession of cascades and rapids. In front of this canyon, between the granitic escarpment and the main volcanic area, an immense mass of débris, partly angular and partly waterworn, has been lodged. This débris clearly represents the material excavated in the canyon since the late Tertiary dislocation. At first glance it is difficult to understand why a postandesitic depression of 2,000 feet should not have affected the volcanic area drained by the East Fork. The answer is that it undoubtedly did affect that area, but that the dislocation along the scarp passed into a gradual flexure in the andesites.

Carson Valley, in the northern part of the quadrangle, is about 12 miles wide and forms a plain sloping gradually from an elevation of 5,000 feet at the foothills of the Pine Nut Mountains to about 4,700 feet at the foot of the escarpment. No remains of the deposits of the lake which in Quaternary time filled the lower part of the Carson drainage basin and which was designated by Russell Lake Lahontan are found in this part of the valley. At Dayton the level of the lake was determined by Russell to lie at an elevation of 4,375 feet, and it is therefore unlikely that this lake ever extended to the Carson Valley, above the city of Carson.

To the east of Carson Valley extends a wide area of gently westward sloping foothills, above which, at an elevation of 6,500 feet, project the more abrupt ridges of the Pine Nut Mountains. These foothills are covered by beds of volcanic tuff and fine gravel, which uniformly dip about 5° W. They are apparently overlain by or change into normal andesite tuffs near the East Fork of Carson River, but they are later than the older (early Tertiary or Cretaceous) andesite of the Pine Nut Mountains. They are regarded as of later Tertiary age and their present position shows that they were tilted westward probably by the same movement which now tends to sink Carson Valley. The whole trend of the evidence therefore tends to show a differential sinking of the area from the foot of the main escarpment to the Pine Nut Mountains and produces the impression of an even tilt of the sunken area toward the west.

The steepness and evenness of the main granitic fault scarp of Antelope Valley, in the extreme southeastern part of the quadrangle, suggest topographic youth, and this suggestion

is confirmed by the entire absence of débris fans and by the way in which West Walker River follows the base of the escarpment. There are at this place no volcanic rocks, but additional evidence of postandesitic displacement is found in the peculiar relations in Slinkards Valley. This valley occupies a longitudinal depression parallel to the main scarp; whether this depression is erosional or structural is left undecided. It is now filled by an even sheet of débris sloping northward after the manner of such accumulations at the bases of desert ranges. At the lower (north) end of the valley this sheet ceases abruptly, the valley contracts, and a canyon begins which swings to the east and cuts across the main escarpment. The vertical distance of 500 feet between the lower end of the Slinkards Valley débris fan and the level of Antelope Valley is held to indicate the amount of postandesitic displacement along this scarp.

MINERAL DEPOSITS.

The mineral deposits of the Markleeville quadrangle comprise several types not usually found on the western slope of the Sierra Nevada. There are practically no Tertiary auriferous gravels underlying the andesite in the bedrock depressions, nor are there any Quaternary gravels of much importance. A little placer work was done in the Silver King district, in the southeast corner, and some Quaternary gravels have been washed on the western slope of the Pine Nut Mountains. The oldest deposits are probably those in the metamorphic area in the granitic region. Near Genoa the amphibolites contain some copper and gold. The metamorphosed sediments near Stevens Peak and Hope Valley contain, near the contact with the granodiorite and limestone, contact-metamorphic deposits carrying pyrrhotite, chalcopyrite, and bornite, the principal gangue mineral being garnet. These deposits contain principally gold, copper, and silver and have yielded a moderate production.

In the Pine Nut Mountains are contained gold-bearing quartz veins, which, however, are narrow and irregular in extent and pay. The Red Canyon mines are entirely in the granite and have been worked to some extent. Others are found in the old andesites. Most of the gold is apparently contained in the sulphides and is set free by oxidation. The andesites also contain large zones of solfataric alteration in which deposits yielding principally silver have been found.

The most important deposits economically are contained in the central mass of andesite southeast of Markleeville, near Monitor, and also somewhat farther south at Silver Mountain. Near Monitor an area comprising many square miles has been altered by thermal waters to propylitic rock in which abundant epidote and chlorite have developed. The altered rocks comprise both breccias and massive andesite. In the central area, between Mount Bullion, Monitor, Mogul, and Leviathan, the rocks have suffered extreme alteration and now appear as white, yellow, and red outcrops consisting of jaspery and chalcedonic rocks as well as kaolin. In places these rocks are rich in sulphides, principally pyrite, but also argentite and various rich silver antimonides. Zinc blende, chalcopyrite, pyrargyrite, enargite, and galena also occur. No well-defined veins could be seen. The copper occurs principally near Mogul and Leviathan.

In the Mogul and Monitor district the claims affording the principal production are said to have been, from south to north, the Colorado, North Colorado, Polaris, Stella, and Orion, the latter two near Mogul. The district has yielded principally silver, but also some gold.

In the Silver Mountain district similar ores have been found, the valuable part of which is said to have consisted of pyrargyrite. The only deposit from which a considerable production has been derived is said to be the IXL-Exchequer, from which many years ago ore to the value of $100,000 is reported to have been taken.

These districts were discovered many years ago, and from 1860 to 1880 were the scene of extensive mining operations. The total production has probably not exceeded $1,000,000. The ores proved difficult to treat and during the last 30 years the production has been almost negligible. From 1896 to 1908 the total output of Alpine County was only $42,430 in gold and $5,921 in silver.

CHAPTER 18. THE CARSON QUADRANGLE.

GENERAL GEOLOGY.

The Carson quadrangle adjoins the Truckee quadrangle on the east and the Markleeville quadrangle on the north. It lies entirely within the State of Nevada, the State line forming the western limit. A part of Lake Tahoe occupies a narrow strip in the southwest corner, and alongside the lake, delimited by fault scarps and continuing toward the northern boundary line, not far from Reno, extends the most easterly block of the Sierra Nevada. Along the center of the quadrangle lies a series of deep depressions at an elevation of about 5,000 feet, sinking to 4,500 feet near the northern edge. These depressions, from south to north, are Carson Valley, Eagle Valley, Washoe Valley, and Truckee Meadows; they lie from 1,200 to 1,700 feet below the level of Lake Tahoe and separate the Sierra Nevada from the desert ranges of the Great Basin, the first of which occupies the whole eastern part of the quadrangle. In the southeast corner of the quadrangle lies the north end of the Pine Nut Mountains. About the middle of the quadrangle Carson River cuts its way through a lower part of that range in a steep canyon similarly to the Truckee Canyon farther north, and then continues eastward into the gradually widening basin of the Carson Sink. North of Carson River rise the Washoe Mountains and the Flowery Range, and in this part of the quadrangle the celebrated Comstock mines are situated. These desert ranges attain maximum elevations between 7,000 and 8,000 feet and are composed mainly of volcanic rocks. Among these rocks andesites predominate; many of them are apparently of late Tertiary age, similar to those of the Sierra Nevada, but others are decidedly older and in places show a transition to holocrystalline forms entirely unknown in the andesites of the Sierra Nevada. There are also smaller areas of granite and patches of older sediments which, from some fossils found near Dayton, are believed to be of Triassic age.[1]

The elevations along the Sierra are decidedly higher and reach 9,000 and 10,000 feet, or more, the culminating point being Mount Rose (10,800 feet), north of Lake Tahoe.

The main part of the narrow buttress separating Lake Tahoe from the central valleys consists of a granodiorite which in places is dioritic. Embedded in this rock are two bodies of older sedimentary rocks, at Carson and at Genoa. In both areas they consist of slates with some nonfossiliferous limestone and a considerable quantity of amphibolitic rocks, probably altered andesites or basalt; in many places the latter are rich in epidote.

In the southern part of the quadrangle scattered areas of andesitic rocks cover the granodiorite. In Little Valley the andesite is underlain by some rhyolite and auriferous gravels. At the north end flows of andesite, extending within a few miles of Reno, almost completely cover the underlying rocks. The thickness of these flows, which culminate in Mount Rose, probably amounts to 3,000 or 4,000 feet. In contrast to conditions farther west, massive flows prevail. At several places the rocks have been altered by hydrothermal processes and their outcrops now assume white and yellow colors. The summits north of Mount Rose are veneered with thin flows of basalt of a late date of eruption. They were extruded near the summit, but their flows, which follow the present slopes, descended on the west to Truckee River in fiery cascades. A smaller basalt area covers the granite at Steamboat Springs, where a group of hills in the central valley form an outlier of the Washoe Mountains.

Lake beds of late Tertiary age are exposed at Verdi, a little north of the extreme northwest corner of the quadrangle, at the foot of the slope, where the andesites reach Truckee River. Some Tertiary lake beds are shown in the vicinity of Carson, especially at the State prison. The beds at this place are of small area and consist of coarse sandstone in which were found

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey No. 208, 1903. p. 123.

tracks of mammals and vertebrate remains consisting of fragments of tusks and molars of an elephant and fragments of bones of two species of horse.[1] These beds are held to be of late Tertiary age. The only large exposures of Tertiary lake beds are found in the western foothills of the Pine Nut Mountains and continue into the much larger area of similar beds described in the chapter on the Markleeville quadrangle. The beds dip west at angles of 5° to 10°.

With these exceptions the Quaternary beds of the central valleys consist almost entirely of sands. According to Russell, Lake Lahontan reached only to an elevation of 4,375 feet (at Dayton), and there is no indication by terraces or otherwise that these central valleys were occupied by any branches of this lake. Still, it is probable that at some time during the Quaternary they have been covered by shallow water. This is indeed clearly indicated by the present conditions in Washoe Valley, where part of the lake still remains.

Glaciation probably did not reach the central valleys and was confined mainly to the higher portion of the Sierra Nevada. There are indications that on the western slope the ice streams extended down to the level of Lake Tahoe.

STRUCTURAL FEATURES.

The most remarkable structural feature in the Carson quadrangle is the high and narrow ridge which, bounded by dislocations on both sides, continues for about 20 miles from Genoa due northward to the latitude of Steamboat Springs. It lies between Lake Tahoe on the west (elevation, 6,225 feet) and the central valleys of the quadrangle on the east (elevation, about 5,000 feet). At the southern boundary its width is 6 miles and at the north end of Lake Tahoe it narrows to 4 miles. At Carson, on the east side, a projecting mass increases the width to 8 or 9 miles. The maximum elevations are between 9,000 and 10,800 feet.

The old surface, antedating the faults, is still visible at favorable places along the summit of the ridge, as near Marlette Lake and in the vicinity of Genoa Peak. This is believed to represent part of a Cretaceous topography of somewhat accentuated features. Patches of andesite flows rest on this uneven surface. Toward the north end extensive andesite flows almost entirely cover the range and show no faulting, while their contacts with the granite clearly indicate that the range, with its eastern slope, existed in preandesitic time—that is, prior to the close of the Tertiary. In all probability the differentiation of the Sierra Nevada from the Great Basin dates back to the late Cretaceous.

The fault scarp which descends to the level of Lake Tahoe is abrupt, but not so evenly marked as that on the east side. South of Glenbrook the slopes are only moderately steep, but, on the other hand, near Marlette Lake the escarpment is extremely precipitous and about 2,500 feet in height. Viewed from a steamer on the lake this fault scarp, contrasting with the more gently undulating old topography at the top, forms an object of exceptional interest and distinctness. It has been assumed that this whole western fault line is at least as old as early Tertiary or Cretaceous, and this opinion must be adhered to, although at some places its appearance is decidedly youthful. Near the north end of Lake Tahoe this escarpment appears to die out and is probably replaced by a parallel fault line just west of State Line Point. There is at this place nothing to indicate that the andesites have been faulted, and this, of course, confirms the conclusion that the scarp is of preandesitic age. Farther south, at Glenbrook, a smaller flow of andesite descends the slope to the lake level without evidence of faulting.

The eastern fault scarp is long and markedly abrupt. Beginning at West Carson Canyon, in the Markleeville quadrangle, it extends with majestic front as a practically unbroken granitic wall up to the northern part of the Carson quadrangle, where the andesite flows begin to cover it. Toward Reno the volcanic hills, which veil the continuation of the scarp, sink to the level of Truckee River.

The greatest declivities are at Genoa Peak and at Slide Mountain, where the amount of the descent to the east is 4,000 feet or more in 2 miles. There is at the foot of this slope a remarkable absence of débris fans as far north as Washoe, but from Washoe up to Reno, where andesites

[1] Le Conte, Joseph, On certain remarkable tracks found in the rocks of Carson quarry: Proc. California Acad. Sci., Aug. 27, 1882.

form the main part of the ridge, débris slopes extend for 2 to 4 miles into the valley. This would seem to indicate a comparatively recent subsidence along the scarp from Washoe southward and, as stated above in the description of the Markleeville quadrangle, this whole fault line, from West Carson Canyon to Washoe, a distance of about 40 miles, has suffered repeated dislocations.

In detail there is probably much more than a single fault. At many places the granitic rocks are extremely crushed and in Little Valley John A. Reid [1] has shown the existence of several parallel north and south faults indicating a gradual settling down toward the east, en échelon. The question is how much of the dislocation was effected at the different epochs of movement. This is a difficult question to answer, as the region has not been examined in great detail. North of Mount Rose the movement on the fault is probably of preandesitic age. South of that landmark postandesitic movement has certainly taken place. Concerning the total amount of postandesitic dislocation along the main part of the scarp no conclusive proof can be obtained, but some inferences may be drawn from the occurrence of gravel underneath rhyolite near the head of Little Valley, northwest of Carson. This is a longitudinal valley draining northward in the center of the main ridge and finally finding an outlet through a steep gulch in the escarpment at Franktown. The gravel is well washed and contains some gold, and, although faulting has somewhat obscured its original character, the inference is safe that it was not deposited while the topographic conditions were the same as they are to-day. It is difficult to agree with Reid in considering these gravels as representing a stream of some magnitude. It is more probable that they were of local origin, but they must have been deposited at or near base-level conditions. At present they are 2,000 feet above the valley at Franktown, and, while recognizing that more detailed study of this locality is necessary, the writer believes that the present vertical distance, about 2,000 feet, approximately represents the magnitude of the dislocation. The appearances suggest that this dislocation was caused by a sinking of the east side.

About a mile north of Genoa small débris fans at the foot of the escarpment have been faulted in recent time. The more complete evidence from Walleys Hot Springs has been described in the chapter on the Markleeville quadrangle. No positive evidence of late Quaternary faulting has been obtained farther north.

MINERAL DEPOSITS.

In regard to the mineral deposits of the quadrangle interest would, of course, center in the great Comstock mines of the Washoe Mountains, which, for many years, annually yielded gold and silver to the value of many million dollars and which still continue a production of notable extent. The purposes of the present paper limit the discussion to the Sierra Nevada and in this part of the quadrangle the mineral wealth is scant. Some deposits of copper and gold have been prospected in the amphibolites of Genoa. At the head of Little Valley, about 8 miles west-northwest of Carson, gold-bearing gravels underlie rhyolite and rest on granite bedrock. The relations are here disturbed by faulting and the exact configuration of the gravels is difficult to ascertain. Washing on a small scale was carried on a number of years ago and the total production is reported to be about $100,000.[1] With these exceptions the western ridge of the quadrangle contains no deposits of economic importance.

[1] A Tertiary river channel near Carson City, Nevada: Min. and Sci. Press, vol. 96, 1908, pp. 522-525; the geomorphogeny of the Sierra Nevada northeast of Lake Tahoe: Bull. Dept. Geology Univ. California, vol. 6, No. 5, 1911, p. 158.

CHAPTER 19. THE JACKSON AND BIG TREES QUADRANGLES.

GEOLOGIC FEATURES.

The Jackson and Big Trees quadrangles form a rectangular area 35 by 54 miles in extent, which contains a considerable part of the foothills and middle slopes of the Sierra in Amador, Calaveras, and Tuolumne counties. It is drained by Mokelumne, Calaveras, Stanislaus, and Tuolumne rivers, the two first named debouching into the lowest foothill region near the western boundary, which is occupied by tuffs, gravels, and sandstones of the Ione and later formations. The first complex of older rocks adjoining the Sacramento Valley may be called the Mother Lode belt. It is 10 to 12 miles wide and consists of intricately intermingled strips of the Mariposa formation (Jurassic), Calaveras formation (Carboniferous), post-Jurassic greenstones, and serpentines. The Mother Lode belt is adjoined on the east by the main mass of the Calaveras formation, which is about 15 miles wide and contains several smaller bosses of intrusive diorite or granodiorite. In the western part of the Big Trees quadrangle lies the contact line between the Calaveras formation and the main area of the intrusive granodiorite of the Sierra Nevada, which extends for about 35 miles toward the east up to the crest of the mountain range. The contact line is irregular, with deep embayments and projecting points.

That part of the great crust block which is represented by these two quadrangles has apparently suffered no important Tertiary or post-Tertiary faulting or deformation, except the general westward tilt characteristic of the whole Sierra. This conclusion is decidedly corroborated by the general fact that the Tertiary channels have not been deformed or faulted. There are some minor exceptions to this statement, especially in the vicinity of Mokelumne Hill.

GOLD-BEARING AREAS AND PRODUCTION.

The auriferous slates and associated rocks contain gold-quartz veins throughout. The main granitic area occupying the largest part of the Big Trees quadrangle is on the whole barren of gold deposits. As in the Pyramid Peak quadrangle, the streams, ancient or modern, become auriferous on passing the main granite contact. But the distribution of the primary gold deposits is far from being uniform. The slate and greenstone belts of the lowest foothills contain few deposits of value. The more easterly part of the belt of Mariposa formation and greenstones from Carson Hill and Angels on the south to Plymouth on the north is followed by the highly productive veins of the Mother Lode. The broad belt of the Calaveras formation has been much less productive, although it contains a number of important mines, for instance at Sheep Ranch and Murphy. Many of the small areas of diorite or granodiorite contained in the Calaveras formation or the deepest embayments from the main granite mass prove to be important centers of mineralization. This is shown, for example, near West Point, Mokelumne Hill, the Sheep Ranch mine, and Vallecito. For details the reader is referred to the Jackson and Big Trees folios.[1]

The richness of the auriferous gravels reflects these conditions more or less clearly. On the whole, the Tertiary gravels are, however, distinctly less rich than in the more northerly quadrangles. This is due partly to the distribution of the old drainage channels, but also no doubt to a shorter period of accumulation. The bulk of the gravels are interrhyolitic, and the rich prevolcanic detrital masses of the Colfax, Smartsville, and Downieville quadrangles

[1] Nos. 11 and 51, Geol. Atlas U. S.

are but sparingly represented in this area. Although the Quaternary gulch and stream gravels below the Mother Lode were rich, it so happens that no important Tertiary streams crossed the most productive parts of the Mother Lode. The most prominent gravel areas are located at Mokelumne Hill, Valley Springs, San Andreas, Altaville, Vallecito, Douglas Flat, Columbia Hill, and from Railroad Flat to the Sheep Ranch mine. Of these the gravels at Mokelumne Hill were doubtless the richest.

The production of placer gold has steadily dwindled until lately, when dredging operations were begun. With careful management many gravel channels as yet untouched would probably give good returns. There is some hydraulic ground, but the late operations have been confined to drifting. In 1905 Calaveras County produced $302,000 in placer gold. About $203,000 of this sum was derived from dredging operations in modern streams. One of these dredges is located near Camanche, on the lower Mokelumne, and the other at Jenny Lind, on the lower Calaveras. Mokelumne Hill produced $16,000, chiefly from drifting; San Andreas $55,000, from one hydraulic and one drift mine; and Douglas Flat and vicinity a few thousand dollars. The county contained 2 dredges, 3 hydraulic mines, 9 drift mines, and 10 surface mines, not counting the small operations of the Chinese.

Amador County in 1905 produced only $49,000 in placer gold; most of this came from Chinese operations.

The production of the placer mines of Tuolumne County in 1905 was only $13,394.

In 1909 the production of placer gold from Amador County in the Jackson quadrangle was $41,800, derived from a great number of small drift and sluice mines at Oleta, Volcano, and Lancha Plana. In the part of Calaveras County contained in the same quadrangle the yield was $257,000, distributed about as follows:

Placer gold produced in part of Calaveras County within Jackson quadrangle, 1909.

Dredging near Jenny Lind and Wallace	$212,000
Valley Springs	1,200
San Andreas, Fourth Crossing, etc	10,000
Mokelumne Hill (mainly drift mines)	11,600
Railroad Flat	9,600
Small and scattered	12,600
	257,000

The Big Trees quadrangle has a comparatively small placer production, approximately $8,800 in 1909, distributed as follows:

Placer gold produced in Big Trees quadrangle, 1909.

Calaveras County:	
Douglas Flat and Vallecito	$2,300
Sheep Ranch and Murphy	1,900
Tuolumne County: Columbia Basin	4,600
	8,800

OUTLINE OF TERTIARY HISTORY.

The Tertiary record of deposition of this district has been established most carefully by H. W. Turner.[1] The earliest deposits are prerhyolitic river gravels, but there are only small amounts of such material in the old river channels. During this epoch, which probably corresponds to the earliest Tertiary, the boundary between the "Bedrock series" and the superjacent formations was probably situated many miles farther west than now.

Then followed in middle Tertiary (Miocene) time the transgression of the Ione formation up to present elevations of about 1,000 feet, indicating a considerable submergence underneath the brackish waters of the gulf which then occupied the great valley. This formation attains its maximum development in the Jackson quadrangle. The lower portion of the series,

[1] Jackson folio (No. 11), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

composed largely of white clay, is well exposed around Ione, whence the formation takes its name. Farther south the white clays are overlain by sandstone, above which is a fine-grained clay rock. The lower white clay is in places quite free from grit and is used in making pottery. Other portions are sandy. The formation contains iron-ore and coal seams. The sandstone is used for building purposes. It is usually white, but at one quarry a brick-red variety colored by finely disseminated hematite is obtained. At other localities it is rusty and contains pebbles of white quartz, passing into a conglomerate. A hydrous silicate of alumina occurs abundantly in the sandstone in the form of cream-colored pearly scales.

The clay rock occurring above the sandstone is light gray, but usually more or less discolored.

The thickness of the Ione formation is known partly by natural exposures, partly by boring. In Jones Butte the strata, protected from erosion by a lava cap, are 200 feet thick above coal mine No. 3. A boring at the mine is said to have penetrated sandy clay to a depth of 800 feet below the coal seam, which is 60 to 70 feet below the surface. Thus the Ione beds appear to be more than 1,000 feet thick at this point.

To the east of Buena Vista Peak the formation has a visible thickness of 600 feet. The table-land south and southwest of Buena Vista is composed chiefly of the Ione formation, overlain by rhyolitic and andesitic tuff and Neocene shore gravels. The lower clay occurs at the east base of the table-land, and a patch of Ione sandstone caps Waters Peak, a little farther east, which has an elevation of about 900 feet.

In the northern quadrangles the Ione formation is contemporaneous with prevolcanic bench gravels along the Tertiary rivers of the Sierra Nevada. In this region it is evident that an epoch of moderate erosion followed the deposition of the Ione, and that most of the gravels contemporary with the Ione were swept out of the Tertiary river.

The rhyolitic epoch followed, and this was preeminently one of accumulation of gravels. The broad valleys became filled by a series of gravels containing rhyolitic pebbles and by interbedded masses of rhyolite tuff, the thickness of this detrital series reaching in places 400 feet. This great depth was observed by Turner near Mountain Ranch. A more compact flow of rhyolite or rhyolite tuff capped these gravels, and its remnants indicate to-day the deeper part of the Tertiary valleys. At the mouths of the rivers thick nonauriferous shore gravels (or delta gravels) spread out at a present level of about 500 feet, and these gravels rest on the gently eroded surface of the Ione formation. (See Pl. XI, *B*, p. 72.)

About this time the tilting of the Sierra and the eruptions of andesite began. A short epoch of erosion intervened before the time of the most intense eruptive action, and during this interval the rhyolitic gravels were trenched in places and temporary interandesitic channels were established, few of them, however, continuing long enough to excavate below the bed-rock of the earlier channels. Then followed the great flows of andesitic tuff, which covered a large portion of the Jackson and Big Trees quadrangles and obliterated the Tertiary channels. Thick masses of volcanic tuff and sands were spread over the Ione formation.

The relations of the Ione formation, the Tertiary and Quaternary shore gravels, and the andesite tuff are especially well shown near the Comanche bridge, on the north side of Mokelumne River.

TERTIARY TOPOGRAPHY.

DRAINAGE.

The Tertiary topography of the Jackson and Big Trees quadrangles can be studied in considerable detail, owing to the many areas of gravels and volcanic rock which the erosion has left intact. The study confirms the conclusions reached in the more northerly quadrangles, and shows that the range existed in Tertiary time; it was much lower, and exhibited some striking characteristics of an older eroded surface, but as a structural unit it was essentially similar to the Sierra of to-day.

Near the northern boundary a small stream flowing westward contained part of the present Cosumnes and Mokelume drainage. It rose near Mokelumne Peak, in the southern part of the

Pyramid Peak quadrangle, and continued into the northern part of the Jackson quadrangle, receiving two important tributaries from the north, which may be called the Fort Grizzly and the Grizzly Flat branches. It continued its course by way of Oleta, Volcano, and Plymouth, emptying into the gulf at some point due west of Plymouth, but its lowest reaches have been destroyed by erosion. This may be called the Tertiary Mokelumne River.

Near Valley Springs a stream of great importance debouched into the valley; it embraced parts of the present drainage areas of Mokelumne, Calaveras, Stanislaus, and Tuolumne rivers, and may be designated the Tertiary Calaveras River. It possessed in striking degree the alternating longitudinal and transverse stretches characteristic of the Sierran Tertiary rivers; its headwaters were located in the Dardanelles quadrangle, of which the geologic survey is not yet completed. The main branches crossed the Tuolumne near the Bradford mill, in the eastern part of the Big Trees quadrangle, and the Stanislaus near Mount Knight, in the same vicinity. The two branches united near Deer Creek and continued westward to Douglas Flat, Vallecito, and Altaville, but bent to the northwest at Altaville and continued in this direction for 12 miles to Central Hill, northwest of San Andreas. Here the direction changed to southwest and the stream emptied into the gulf at some place west of Valley Springs. An important tributary called the Fort Mountain channel came down with a north-south course along the western margin of the Big Trees quadrangle and the tributary to the west joined the main river near San Andreas. A second tributary joined the main river near Central Hill from the vicinity of Mokelumne Hill. The main Mokelumne branch was again joined by the short Concentrator channel, the direction of which was from north-northwest to south-southeast from Jackson to Mokelumne Hill.

RELIEF.

As farther north in the range, the foothills, or the Mother Lode belt, were characterized by strongly marked longitudinal ridges. In the northwestern part of the Jackson quadrangle this feature is less emphasized than usual and the surface had in part been worn down to a gently undulating peneplain, but at the valley border the "Bedrock series" dipped steeply below the superjacent formations of the Tertiary gulf, as shown at Waters Peak, near Buena Vista, and at other places. South of Valley Springs, however, the longitudinal structure asserted itself strongly, and the Gopher Ridge, Bear Mountain, and Mount Joaquin were almost as prominent in Tertiary time as now. Mount Joaquin towers 1,800 feet above the Central Hill channel at San Andreas, and the Gopher Ridge rises abruptly 1,200 feet from the Ione formation which encircles its base.

East of the Concentrator and Central Hill channels the slate hills of the Calaveras formation rose gradually 1,000 to 1,500 feet in about 5 miles, to a sort of plateau in which the Fort Mountain channel had excavated a broad, shallow valley. South of Jackson there is an excellent cross section of the valley of the Concentrator channel; it is 3½ miles wide and 400 or 500 feet deep. East of the Fort Mountain channel the slate ridges of the Blue Mountains attained a height of over 6,000 feet—that is, a rise of 2,800 feet in 6 miles, allowing for the westward tilting. Farther south, east of Columbia and Douglas Flat, the bedrock hills resisted erosion in a similar manner and the main part of the Tertiary Calaveras River broke through them in a broad valley almost 1,500 feet in depth.

Farther east we enter the main granite area of the Sierra. While there are no auriferous gravels here, the lava-capped ridges give an excellent indication of the character of the surface. There are many inequalities and broad depressions as much as 1,000 feet in depth, but this large area was practically a high plateau which now shows a westward slope of 50 to 100 feet per mile.

GRADES.

The grade of the Tertiary Mokelumne River from the northeast corner of the Jackson quadrangle westward to Plymouth averages 100 feet to the mile; it is a little more near the upper corner and a little less near Plymouth. The grade of the ancient Calaveras River is shown in the following table:

Grade of the Tertiary Calaveras River.

Place.	Elevation (approximate)	Distance.	Grade.	Direction.
	Feet.	*Miles.*	*Feet per mile.*	
Bradford mill	5,000			
Rose Creek	3,200	10	180	West.
Philadelphia mill	2,700	4	122	Do.
Eho mine	2,160	8	68	Do.
Angels Camp	1,450	8	89	Southwest.
San Andreas	1,000	} 16	28	Northwest.
Central Hill	990			

The grade of the south-southeastward-trending Concentrator channel from Jackson to Mokelumne Hill is very slight. On the other hand, the Mokelumne Hill channels, which trend south-southwest, have grades of at least 100 feet to the mile. The Fort Mountain channel, which flowed southward for about 12 miles, has an average grade of 70 feet or less to the mile.

The testimony afforded by the present grades of the main Calaveras River speaks strongly for an even westward tilt of the Sierra of about 70 feet to the mile.

DETAILED DESCRIPTIONS.

The first detailed description of the channel systems of Calaveras County was written by W. H. Storms.[1] In part this is based on the work of C. M. Burleson, surveyor at Mokelumne Hill, who also furnished Messrs. Boutwell and Lindgren with much information in 1901. A large part of the following description of Douglas Flat, Vallecito, and Mokelumne Hill is compiled from notes of J. M. Boutwell, who assisted the writer in the summer of 1901.

VOLCANO AND OLETA.

Little detailed information is available as to the gravel deposits of the Tertiary Mokelumne River in the northern part of the Jackson quadrangle and along the southern margin of the Placerville quadrangle. The location of the remaining parts of the channel and the gravel areas is given in the folios already cited. The main channel from Fort Grizzly (in the Pyramid Peak quadrangle) continues, lava capped, for several miles southwestward down to the heads of Sutter Creek and Ashland Creek, where some hydraulic work has been done. It then continues, after an eroded gap of 4 miles, underneath the lava for 4 miles from Volcano to the head of Rancheria Creek, where it is underneath a capping of rhyolite tuff. These channels probably contain, in part at least, paying quantities of gold. A number of smaller gravel patches have been worked by hydraulicking and drifting near Oleta and between Oleta and Rancheria Creek.

The most productive locality is near Volcano. The bedrock here is limestone, and rich gravels were found in the deep potholes both in the Tertiary channel and in the later gulches. The placer production of Amador County, which roughly speaking is derived from this Tertiary drainage basin, was nearly $50,000 in 1905, of which $40,000 is believed to have been extracted by Chinese miners from various districts; $3,000 came from the mines at Volcano, $1,000 from the vicinity of Oleta, and $2,500 from the vicinity of Plymouth.

THE MAIN CHANNEL.

DOUGLAS FLAT, VALLECITO, AND ALTAVILLE.

The general upper course of the Tertiary Calaveras River is outlined in a previous paragraph. East of Douglas Flat very little remains of its gravels, the first 10 miles being almost wholly eroded by the forks of Stanislaus River; the course farther east is hidden under andesitic tuffs. This upper course underneath the andesite in the main granite area is clearly indicated by the course of the contacts of lava and granite, but it is not likely to contain paying gravel deposits.

[1] Twelfth Rept. California State Mineralogist, 1894, pp. 482-492.

At the sharp bend near Douglas Flat and Vallecito (see Pl. XXVI), very heavy inter-rhyolitic gravels have accumulated in an old valley some 8 miles long and up to 2 miles wide, lying between Tertiary bedrock ridges rising about 1,000 feet above the deepest trough. The prerhyolitic gravels are thin or absent, but the interrhyolitic series attains a thickness of 200 feet. Turner says in the Jackson folio that the gravels 2 miles northeast of Angels are very similar to the Neocene shore gravels about Valley Springs and that they are interbedded with rhyolite tuff and contain pebbles of rhyolite. They are normally overlain by an irregularly eroded sheet of rhyolite tuff which east of Vallecito is 200 feet thick. In places the inter-rhyolitic gravels gradually change into andesitic gravels which form a part of the cap of andesitic detrital material. The andesitic tuffs and gravels aggregate 700 feet in thickness, but are of course irregularly eroded.

Few parts of the channel are accessible by tunnels. Shafts about 100 feet in depth are necessary. There is much water, and this, coupled with the fact that the gravels are not extraordinarily rich, has greatly delayed the exploitation of the channel. About 11 miles of main channel is comprised underneath these gravel areas and only a small portion of this distance has been drifted. It is not unlikely that this ground could be made to pay by operations on a large scale with adequate pumping machinery.

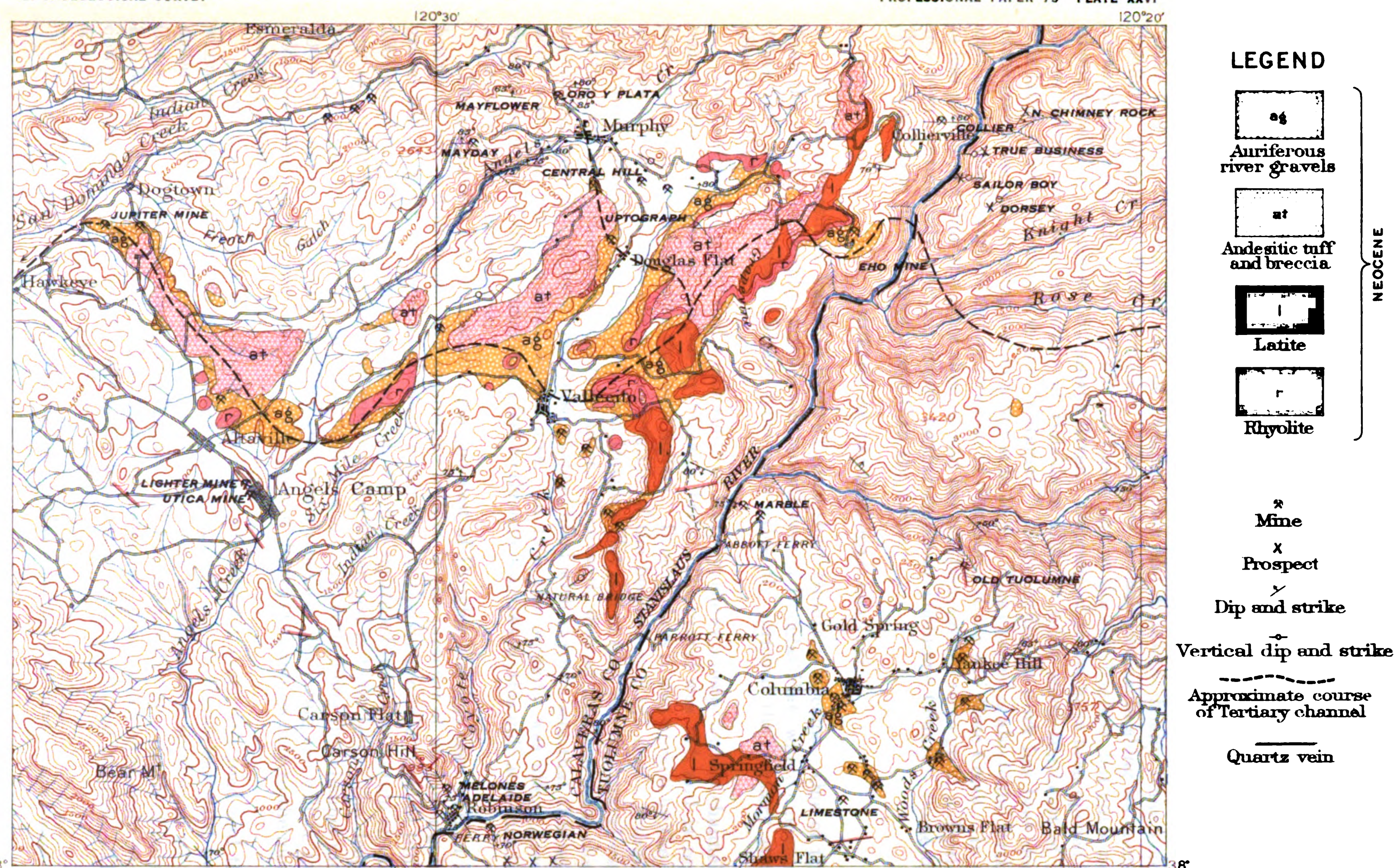
The canyon of the Stanislaus has cut a great gash across the main channel 2 miles east of Douglas Flat and removed a large part of its eastern rim.

The main channel is believed to enter the hill at the Eho mine, on the west side of the Stanislaus Canyon, 1,000 feet above its bottom, about 3½ miles east of Douglas Flat. Near this place it was joined by a tributary, coming down in a southerly or southeasterly direction from the vicinity of Murphy. The main stream course should thence continue south-southwest for 3 miles to a point near Vallecito, where its bottom is probably exposed for a short distance at an elevation of about 1,800 feet. This part could no doubt be reached by tunnel from the canyon slope or by a shallow shaft from the Vallecito side. Much hydraulic work has been done near Vallecito on the upper gravels, but the bottom has been reached only in few places by shafts.

The Vallecito Consolidated Mines control a considerable area between Douglas Flat and Vallecito and it was proposed in 1902 to open the ground by a 7,000-foot tunnel. At a point nearly east of Vallecito the channel has been proved through the Wild Goose shafts. The course of the main old channel is clearly demonstrated east and northeast of Vallecito in the Mitchell and Manitou shafts. It follows a westerly course with high rims to the northwest and southeast.

From Vallecito the channel is practically continuous for 4 miles westward, and after a short gap, where cut by Angels Creek, it continues again under the lava for 4 miles in a northwest direction to the Jupiter mine.

The Eho mine is situated about 3½ miles east of Douglas Flat at an elevation of 2,137 feet, overlooking the junction of Stanislaus River and Rose Creek. Several stretches of the oldest channel have been located for an extent of nearly a mile to a point where it is cut off on the southwest. About a mile west of the Eho mine, at an elevation of 2,700 feet, a shaft is said to have been sunk 500 feet—possibly 800 feet—without striking bedrock. It is thought that the gravels at the Eho mine represent the main inlet of the old river and that from this point the deepest trough continues underneath the ridge in a south-southwest direction to Vallecito. In this distance the channel has not been exposed. A section about 550 feet in thickness, exposed in the slope between these two points, shows just above the bed of the main channel a bedrock rim bearing rhyolitic tuff overlain by gravel containing rhyolite, followed by gravel carrying pebbles of a rock that may be andesite, which is in turn succeeded by 175 feet of rhyolitic tuff, 100 feet of latite, a thin bed of gravel, and finally latite and andesitic conglomerate. In the rear of the Adams ranch a somewhat similar section is shown. Rhyolitic gravel on bedrock at an elevation of 2,025 feet is overlain by rhyolitic tuff, washed gravels, andesitic conglomerate, and a regular andesitic series.



GEOLOGIC MAP SHOWING TERTIARY FORMATIONS AND CHANNELS IN PARTS OF JACKSON AND BIG TREES QUADRANGLES

Geology by H. W. Turner and F. L. Ransome

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level

1911

CATARACT CHANNEL.

In the description of the Table Mountain channel in Tuolumne County (pp. 214–217) mention is made of the long but narrow flow of latite lava which, during an interval in the andesitic eruptions, descended from the direction of the Dardanelles and crossed the Big Trees quadrangle diagonally from northeast to southwest, entering it at Clover Meadow, crossing the North Fork of the Stanislaus near the Calaveras *Sequoia* grove, then following the west brink of the Stanislaus Canyon all along and east of Douglas Flat and Vallecito, finally being continued in Tuolumne County by Table Mountain. This flow is easily traceable along its course by the areas of black basaltic latite. It did not follow any of the old channels, but cut a new course about parallel to the present Stanislaus River. Deposits of gravel have been opened in several places below the latite, especially at Balaklava Hill, 1½ miles south-southeast of Vallecito; this latite channel is known as the "Cataract." Some hydraulic work has been done at the place mentioned and drifting was in progress in 1896. This channel is also found farther northeast on the point overlooking the junction of Stanislaus River and Rose Creek. In general it is less productive than the older channel and has not been eroded to so great a depth. It has not been continuously worked, except farther south in Tuolumne County. Some of the top flows of andesitic tuff are more recent than the latite.

MURPHY OR CENTRAL HILL CHANNEL.

The broad basin of Vallecito received some short tributary streams. One of them came from the vicinity of Murphy, 2 miles north-northwest of Douglas Flat, where numerous quartz veins have been exploited. These veins have evidently enriched the Tertiary stream bed. (See Pl. XXVI.)

The Central Hill mine,[1] half a mile south of Murphy, shows a deep, narrow channel carrying coarse, subangular gravel, capped by volcanic beds. The gravel was rich and is reported to have produced several hundred thousand dollars. In early days it was worked by the hydraulic process at the north end, where the elevation of the bedrock is 2,185 feet. A drain tunnel, 3,300 feet in length, was run in 1894 from Douglas Flat and in that year the gravel was worked by the hydraulic process through this outlet. This work showed that the main channel and its capping were cut off by a transverse channel filled with rhyolite and that this intersecting body was again cut by a small watercourse. In 1901 the property was idle. According to Storms the grade of this channel is 300 feet to the mile southward; this indicates that it is rather a tributary than a main trunk.

The Uptograph (Buckminster) mine just west of Douglas Flat has been worked both as a hydraulic and a drift mine. An interesting feature is the presence of an upper gold-bearing gravel bed in which the gold has been concentrated on the surface of a rhyolite tuff. About 100 feet of rhyolite tuff caps the upper lead, which is separated from the bottom channel by 15 feet of similar tuff. The maximum width of the upper bed is 1,000 feet. The deep channel varies in width from 20 to 100 or even 200 feet, and the gravels filling this channel range up to 100 feet in depth. It should be added that many channels of varying age will be found in a wide basin like the one near Vallecito. The present description applies only to the more important old stream beds.

From the Uptograph the channel was followed eastward, under the road and the creek, where a hole in limestone was encountered carrying rich gravel; thence eastward for a short distance up the ridge, where an irregular pothole was found; thence southward to the Wild Goose shafts. Under the creek near Douglas Flat the bedrock lay at a depth of only 15 feet, but beneath the ridge it is 50 feet, as shown by the shafts. Then it fell off sharply 50 feet, and downstream at the Wild Goose shafts bedrock was at a depth of 210 and 205 feet. The gravel was rich and thick and overlain by rhyolitic tuff.

[1] Not to be confused with Central Hill, which is northwest of San Andreas and from which the main channel is named.

THE MAIN CHANNEL IN THE VICINITY OF VALLECITO.

About a mile northeast of Vallecito the Manitou shaft, descending through rhyolite at the surface at an angle of 75°, struck, at a depth of 167 feet, bedrock pitching south. The gravel opened is made up of well-rounded pebbles, porphyry, and bedrock, neither rhyolite nor andesite being found; like that of the Murphy channel it was cleanly washed and well laid.

Above and 500 feet north of the Manitou shaft a narrow channel 30 to 40 feet wide, carrying quartz sand and gravel capped by rhyolite, has been explored through a series of shafts 40 to 70 feet in depth and appears to be a branch of the Manitou and to join it immediately to the west. At a point about due north of Vallecito in the Ward diggings the channels are reported to have yielded high values in coarse gold. About half a mile east, due north of Vallecito, is a shaft reported to have been sunk by Italians half a century ago to a depth of 146 feet without reaching bedrock. Immediately east of the shaft, and east of the Vallecito Road the main channel is entered by the Mitchell shaft 110 feet in depth (bedrock elevation, 1,675 feet). The shallow channel has been followed from Vallecito to this point.

EAST OF VALLECITO TOWARD ABBOTT FERRY.

East from the Mitchell shaft along the ridge road to the main divide above Tuolumne Branch basin is an extensive area of mixed prevolcanic gravels capped by rhyolite, andesite, and latite, which have been opened at many points. In general the gravels, though well rounded and probably contemporaneous with those of the main Central Hill channel, differ from them in showing less porphyry. Exposures in this region exhibit several features of special interest and probably mark the southeastern rim deposits of the main Tertiary river.

Along the ridge road several old workings show fine, subangular gravel or porphyry, quartz, and slate, apparently resting on a broad rim rather than in any definite channel, and capped by rhyolite and latite. Just below the saddle on the east side a narrow channel affords interesting evidence as to the succession and local disturbance. A section shows limestone bedrock covered by finely laminated sand and shale inclosing angular pebbles. The sand is covered by three beds of gravel interstratified with three beds of rhyolitic sand and two of rhyolitic tuff, the whole capped by andesite tuff and latite. The shingling of the gravels indicates indisputably that the stream in which they were deposited flowed westward. The elevation of the limestone at the outlet is 2,000 feet. The dip of the several beds of the section is now 40° E. to 90°: the cause of this disturbance was not ascertained.

THE MAIN CHANNEL WEST OF VALLECITO.

From Vallecito the gravels extend for 4 miles, first west-northwest, then southwest, under the volcanic flows to a point northwest of Angels Camp, where they are exposed in Angels Creek. They are covered by rhyolite and andesite. Within this distance large portions of the channel remain unworked.

FROM ALTAVILLE TO DOGTOWN.

In the section from Altaville to Dogtown the main channel is marked by an extensive deposit of well-rounded gravel composed of porphyries, quartzite, gneisses, and granite, capped over a considerable part of the area by rhyolite and andesite. These rocks extend from a point less than a mile north of Angels Camp continuously for 4 miles. The channel has been worked in a few localities and found to be comparatively narrow and with gentle grade, averaging less than 50 feet to the mile, and to carry good values. A considerable extent remains unprospected.

East of the Bald Hill property near Altaville the rhyolite gives way on the surface to an extensive area of andesite which extends north for 3 miles, nearly to the limits of these gravels at Dogtown, and probably marks the postrhyolitic channel cut into the white tuff and filled by an andesitic flow. North of the Bald Hill shafts the gravels have been worked on the east side

of the ridge in the Jackrabbit ground and at the north end of the area in the Jupiter property. A section on the east rim of the Jackrabbit property shows bedrock, andesitic tuff, sandy breccia, rhyolitic and andesitic tuff containing pebbles of each rock, andesitic tuff, and andesitic pebbles to the total thickness of 20 feet. The gravels have been opened here by a shaft 191 feet in depth with a 100-foot drift in gravel to the south from its bottom and a lower tunnel running 1,200 feet in bedrock. The gravel has been prospected a distance of 300 feet along the course of the channel and breasted for a distance of 75 feet to a width of 35 feet and height of 7 feet; the gravel extracted is said to have contained from $2 to $10 a cubic yard.

The Monarch pit shows that the rim is overlain by 25 feet of prevolcanic gravel, covered by volcanic material. At this point the channel has been explored through a 500-foot tunnel; some of the gravel is stated to have averaged $5 a ton.

At the north end of this main strip, due south of Dogtown, the gravels in the main Central Hill channel have been worked on a considerable scale on the Jupiter property. The channel here was originally prospected by a tunnel on bedrock extending upstream about 1,500 feet. Subsequently the lower 600 feet was hydraulicked, leaving the tunnel extending beyond under the gravel 700 to 900 feet. It was found that the channel at this point is steep-sided and narrow, averaging 125 feet in width and in one place reaching a width of 200 feet.

The gravels of the channels from Vallecito to the Jupiter mine are evidently not very rich and will probably not pay for drifting throughout.

JUPITER MINE TO SAN ANDREAS.

From the Jupiter mine to Central Hill the course of the channel is northwest by way of San Andreas. Its course is largely eroded but is distinctly indicated by the old valley, as the new streams have cut but slightly below the old bottom. Few small gravel patches still remain; near San Andreas some of these are covered by andesite or rhyolite; most of them have been hydraulicked or drifted. Between the Jupiter mine and Lower Calaveritas no definite channel with characteristic filling was found. Well-rounded bowlders occur scattered over the bedrock at four or five points at elevations accordant with the channel system. Nowhere, however, was any distinct channel in bedrock found. In the area about 2¼ miles southeast of Calaveritas is a pothole 100 feet in diameter at the top, 20 feet at the bottom, and 20 to 25 feet deep, which was filled with washed gravel carrying high values in gold.

Northwestward from Lower Calaveritas to San Andreas the records of the old drainage system are more definite. They indicate that this had been the main drainage course in prevolcanic time and that it continued so in the postrhyolitic and preandesitic epoch. The main channel, which here is regarded as the united main or Central Hill and Fort Mountain channels (see p. 209), has been well proved throughout its extent. The basal thin gravel carried good values at several points and is normally overlain by rhyolitic tuff. A postrhyolitic but apparently preandesitic channel cut down 30 feet below this, and at several points are remains of a shallow, high-lying volcanic channel. Most of the gold is found in the Central Hill channel and a considerable area of this northwest of Willow Creek remained unworked in 1901. The several workings will be described from southeast to northwest.

Immediately northwest of Lower Calaveritas the Gosinelli hydraulic workings have exposed the rim of a channel about 150 to 200 feet wide, trending northwest, in which 15 to 20 feet of rhyolite on the rim lies upon bedrock and is overlain by 10 feet of gravel made up of quartz, quartzite, gneiss, granite, and porphyry, 12 feet of sand, and 25 feet of coarse gravel. Half a mile northwest and 55 feet lower are the Johnson workings; at this place the bedrock channel, about 100 feet in width, trends northwest. The succession overlying the schist bedrock at this point is 5 to 8 feet of gravel, consisting of quartz and metamorphic rocks, 15 to 20 feet of rhyolite, 25 feet of quartz sand, and gravel, and 15 feet of mixed washed gravels. At the Hedrick property, one-fourth mile farther northwest, a pit 200 feet in length has been hydraulicked. Prerhyolitic gravel is exposed, cut by a later channel, marked by rhyolitic tuff and interbedded rhyolites and gravels, and the combined deposits of these two channels are blanketed over with fine oxidized gravel. The rhyolite carries fossilized leaf remains, and pay was found in both

the lower and the upper gravels. The channel was found by hydraulic work and drifting to be shallow and flaring, 400 feet wide, with a portion 8 feet deeper 100 feet wide. As its bed is fully 175 feet above the bedrock in the main channel at the Marshall workings, it seems probable that this is a higher-lying broad, shallow bench to be correlated with a similar member northeast of the Angels road and immediately to the north near the race track, and again on Cemetery Hill at San Andreas.

On the Marshall property, about half a mile south-southeast of San Andreas, the greatest amount of exploration has been done, thus offering the fullest information regarding this channel system. Five shafts, 108, 100, 105, 127 (with 800-foot drift), and 90 feet in depth, have been sunk in the main channel and two long crosscut tunnels driven eastward into the channels. These together prove the channel for a distance of about 1,500 feet. The main channel is here 50 to 70 feet wide; there is a narrow bench on the northeast 10 feet above it and one on the west somewhat lower and of gentler grade, with rapids and potholes here and there. The succession cut by shaft No. 1 at the north end of the property, which is believed to be generally characteristic of this portion of the channel, is as follows:

Section in Marshall shaft No. 1.

	Feet.
Gravel	42–43
Rhyolite	4– 6
Pay gravel	6
Slate bedrock.	

The pay gravel is made up of pebbles of bedrock including gravel, schist, and porphyry.

At the south end of the workings the deepest shaft (127 feet), with an 800-foot drift to the southeast, demonstrates that at this point a narrow channel trending northwest and southeast cut transversely through the main Marshall channel to a level 36 feet deeper. The gravel is composed of unwashed cobbles and is thus entirely unlike that of the main Marshall channel and so far as opened it did not carry pay values. The relative age of this channel can not be stated with certainty, as it was not accessible at time of visit and the facts reported are not conclusive. As no pebbles of volcanic rocks were reported from this gravel, and the operator believes that the bed of fine gravel with its fine gold content, which lay upon the bottom of the main channel on both sides (rims) of this deeper channel, passes continuously across over it, it would appear that the deep channel is older. On the other hand, it is stated that while rhyolite overlay this bed on both rims, it did not continue across and this suggests that it may have been cut out by the deeper, later channel.

Fossil records of interest were uncovered in the course of the exploration of this property. It is stated by the owner of the property that in a northern shaft two Indian mortars and pestles were found immediately upon bedrock, one of them weighing fully 200 pounds. Petrified wood is common in rhyolite at this point. Leaf impressions were also observed in rhyolite tuff.

Within the town of San Andreas occur the remains of two rich channels, known as the South channel and the San Andreas channel. The elevations indicate that they are the continuation of the deep channel of the Marshall property. Three shafts on Cemetery Knob, on the west side of the Angels road, each 40 feet in depth, and some of the workings on the Marshall property prove the occurrence of a channel trending westward just south of the town, 35 feet below the bedrock rim of the main Marshall channel at that point. To the northwest, near the Hall of Records, it falls rapidly to the west and carries gravel 4 to 8 feet thick that gave high values. Thence westward this channel has been followed and worked under the road. The Combination channel, which passes westward under the north side of the town, lies near the bottom and just north of the present San Andreas Gulch. It has been opened on the east by three shafts and proved to lie at that point (on Pfortner's lot) 43 to 50 feet deep. To the west it has been proved by several shafts and a long ditch. In general these demonstrate a narrow channel trending about N. 70° W.; it is filled with 5 to 8 feet of pay gravel covered by 6 feet of rhyolite tuff and about 100 feet of interrhyolitic gravels. The larger part of these channels has been drifted. Some work of this kind was in progress in 1902.

The records of the main channel system from this locality for some distance downstream are meager. On Gold Hill, in the rear of Hospital Ridge, gravels composed of pebbles of bedrock were found in rhyolite. It appears, however, that the drainage passed north-northwest and in the area now occupied by Central Hill united with the drainage from Mokelumne Hill and then flowed westward to Valley Springs. Before tracing this combined drainage west of Central Hill, however, the northern tributaries, known as the Mokelumne Hill system, will be described.

MOKELUMNE HILL CHANNEL SYSTEM.[1]

GENERAL FEATURES.

The Mokelumne Hill system of channels extends from Mokelumne Hill on the north to Central Hill on the south, a distance of 6 miles, with an average width of less than 2 miles. (See Pl. XXVII.) It embraces 8 distinct channels and remnants of others, ranging in age from prevolcanic to late volcanic. In general, it thus indicates that through a period of time covered by the records of the ancient drainage systems of this region, the narrow northeast-southwest zone now occupied by the gravels of the Mokelumne Hill system was a valley, and that this valley persisted throughout as the main southward outlet of the drainage from the north. To the north and northeast of Mokelumne Hill the Tertiary deposits of this valley are eroded, but it is probable that the streams headed less than 10 miles distant in this direction. An important tributary flowing in a south-southeast direction from the vicinity of Jackson joined the main stream near Mokelumne Hill.

The channels show by their wide differences in elevation deep dissection in this period. Thus from the highest to the lowest an erosion of approximately 700 feet is recorded. As a whole, the grades of the channels of this system are rather steep. In this area relative elevation is not a safe basis for the determination of relative age, as has been assumed by some; for example, the main prevolcanic channel is one of the low-lying channels, while late ones, even postvolcanic, are among the highest in elevation. Moreover, relative age is not in this area an index of value, as the main prevolcanic channel of earliest date and one of the latest of the postvolcanic channels are the richest among the number. The channels include the Deep Blue, Tunnel Ridge, Gopher, Corral Flat, Stockton Ridge, Concentrator, Duryea, Kraemer, and Chili Gulch. That they were formed under different conditions is proved by the difference in grade, in form of bedrock channels, in position and character of gravels, and in succession and character of filling materials. The most profitable deposits have proved to be those of the Stockton Hill, Chili Gulch, and Deep Blue channels. They were worked in the earliest days of gravel mining in California, and the main portions of the channels in this system, after yielding large amounts of high-grade gravel, are now usually regarded as about exhausted. The locality, probable course, and general characteristics of each of the channels are given below. (See Pl. XXVII.)

CORRAL FLAT CHANNEL.

Remnants of high-lying gravel deposits known as the Corral Flat channel were found a short distance northeast of Mokelumne Hill, at French Hill, and portions of this stream are believed to have traversed the Stockton Hill area. At French Hill hydraulic work has exposed a definite portion of a north-south bedrock channel overlain by mixed volcanic gravels, and these fragmentary exposures seem to show remnants of banded ferruginous bedrock gravel blanketed by a succession of rhyolitic tuffs, muds, and gravels, the whole cut to bedrock by postandesitic channels filled with bowlders of andesite and a capping of andesitic breccia.

STOCKTON RIDGE CHANNEL.

At the north end of Stockton Ridge, within the southern limits of the town of Mokelumne Hill, occur gravels of a high-lying drainage system, known as the Stockton Ridge channel. The deposits are believed to belong to one of the earliest drainage epochs in this area, if not to

[1] Mainly from notes by J. M. Boutwell.

the earliest. They were among the first in this country to be worked, and as the gravels were very rich claims were limited to small areas. As a result, that portion of Stockton Ridge thus opened is closely dotted with old abandoned shafts. None of these workings were accessible at the time of visit, however, and little could be learned beyond the fact that the general course of the deposit was southward and that the values ran very high. It is probable, to judge from the deposits, that the gold which, after the heavy rains of to-day is readily washed from the gravels and streets of the town, is derived from the tailings of the washings of the gravels of Stockton Ridge in early days. Later, work in this vicinity through several deep shafts, one of which has been sunk to a depth of 375 feet, has demonstrated that other deep-lying channels of later date traversed this area, and they doubtless truncated those of the Stockton Ridge system.

GOPHER CHANNEL.

About 3½ miles northeast of Mokelumne Hill, exposures of coarse, rounded bowlders of quartz and siliceous bedrock are found upon unworn bedrock at an elevation of 1,835 feet. West of these occur similar deposits on a washed and tunneled bedrock surface at the low elevation of 1,736 feet, and west of the divide are similar deposits. Still farther to the west and lower, at a point 2 miles east of Mokelumne Hill, a narrow, sinuous north-south gorge 400 to 500 feet long and 60 to 75 feet wide is filled with 5 to 8 feet of prerhyolitic gravel which is overlain by rhyolitic tuff. The grade is very steep; the rims 25 feet above are still steeper and exhibit a similar succession of gravel, rhyolite, sand, and gravel. At the Gopher workings this channel swings westward in a broad crescent and shows in both side pit and main pit gravel of three distinct ages—prerhyolitic, rhyolitic, and postrhyolitic. The lowest and oldest member, here 15 feet in thickness, is made up of coarse, siliceous, cemented gravel with angular blocks of slate near the top; the middle member comprises lenses of rhyolitic tuff with interbedded detrital members filling channels incised in tuff; and the third includes subangular, poorly assorted gravel. Hydraulic operations at that point have exposed a channel in bedrock 75 to 100 feet in width for a distance of over 300 feet, with high, steep rims.

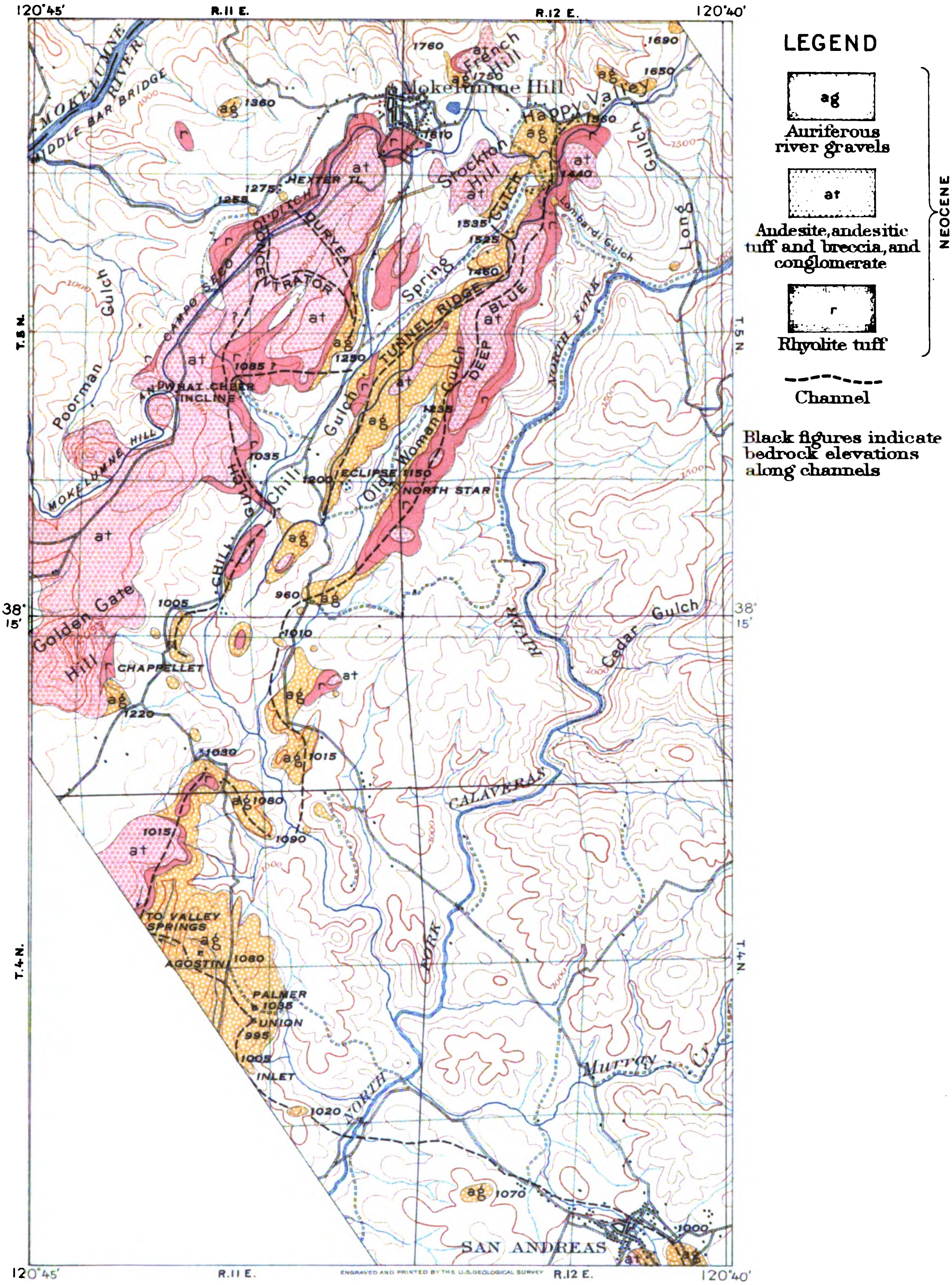
The connection of this channel to the south is uncertain. It has been correlated with the Tunnel Ridge channel. Storms supposed that it swung north of French Hill down through the western part of Mokelumne Hill and southeast into Chili Gulch to connect with the known Chili Gulch deep lead.

DEEP BLUE, OR NORTH STAR, OR OLD WOMAN GULCH BLUE LEAD.

The Deep Blue lead (known also as the North Star, after the name of the company which is its chief owner and operator; also as the Old Woman Gulch Blue lead, after the name of the gulch followed by this channel) is one of the most important and best-known channels in this entire system. It has been explored at the north end in Buckeye Gulch through the original North Star tunnel, driven south along the channel; a short distance farther south at Curnows by a deep shaft, at the North Star pit, by hydraulic work, at the Combination incline, 505 feet long (vertical depth 132 feet), with transverse drifting; farther downstream and to greater depth by the Empire incline; and at the south end, north of Central Hill, by a series of hydraulic workings.

The width of the channel varies considerably but appears to average about 200 feet. The channel has been found to follow a general southerly course from Buckeye Gulch under the southeastern slope of Old Woman Gulch to a point within about a mile of Central Hill. Its elevation is neither extremely high nor low, but rather intermediate, varying from 1,440 feet at the north to 1,150 feet about 3 (?) miles farther south and 950 feet in pits at the south end. This fall shows a grade of over 100 feet to the mile.

The gravel of the main or lower lead is made up mostly of quartz and bedrock without pebbles of Tertiary volcanic rock, and much of it is cemented. This is overlain by olive-colored clay and this by rhyolitic tuff, above which, approximately 50 feet above bedrock, is an upper deposit of gold-bearing gravels, finer than the lower constituent of the upper lead.



From Mother Lode District sheets
U. S. Geological Survey

Geology by F. L. Ransome. Channels outlined by J. M. Boutwell and W. Lindgren

GEOLOGIC MAP SHOWING TERTIARY FORMATIONS AND CHANNELS BETWEEN SAN ANDREAS AND MOKELUMNE HILL

Scale $\frac{1}{63360}$

1 ½ 0 1 2 Miles

1 ½ 0 1 2 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

1911

Special search was made for evidence bearing on the age of the lower gravels. Former workers[1] in this field have held that they should be correlated with the volcanic period. In the present study, however, none of the gravel showed any volcanic pebbles. Accordingly, and in spite of the comparatively low elevation of the channel, it appears to have been cut and the lower gravels deposited in prevolcanic time.

As to its commercial aspects, the lower 5 feet has been found to carry the highest values, but tests are said to have shown that it averages in places $1.50 a ton to a height of over 13 feet. In 1897, 4,031 tons of gravel extracted from the North Star workings in 10 months averaged $1.95 a ton. It was estimated in 1901 that a considerable body of gravel of pay value remained in this channel.

TUNNEL RIDGE CHANNEL.

The upper pit in Happy Valley exposes an east rim of a channel at an elevation of about 1,550 feet bearing subangular, siliceous gravel composed mainly of quartz and bedrock. A few andesitic pebbles appear to have been derived from late breccia, but no other volcanic material was found. The main body comprises 30 to 40 feet of ill-sorted gravel, carrying in one place polished quartz bowlders 5 feet in diameter, and is capped by red-stained gravel and soil. About a quarter of a mile nearly due north the gravels have been extensively worked in the Mosher pit and are revealed in the following section:

General section of main Mosher pit.

	Feet.
Andesitic breccia.	
Brown, apparently andesitic tuff	20
Rhyolitic series comparable to Happy Valley mine section	5–15
Andesitic gravel	0–5
Andesitic breccia tuff	0–6
Coarse gravel, subangular, cemented at south end of pit	5
Fine sand and gravel cut out locally	20
Fine gravel and sand on bench	25
Cemented quartz gravel	3
Coarse, subangular gravel	25
Bedrock.	

This section indicates in general a long period of gravel deposition, during which the gravel was coarse at the base and gradually became finer. The gravel at the south end of the pit and immediately under the rhyolite shows faulting which has brought the cemented gravel opposite to the noncemented gravel. The gravel in the Mosher pit is probably to be correlated with that on the bench in the Happy Valley mine and is overlain here, as there, by the ferruginous cement. It is reliably reported that lower pay gravel was mined continuously from the Happy Valley mine to the Mosher, thus demonstrating their unity. The gravels on the bench at the Mosher pit yielded little pay. The volcanic series capping the channel at these two properties is practically identical though showing considerable shifting of drainage lines. About a quarter of a mile to the south this channel is again exposed by the Lamphyre hydraulic workings, and at this point the main gravel member aggregates 75 feet in thickness, with a coarse angular portion constituting the basal part and fine gravel above, this and the cement resembling corresponding members in the Mosher pit. From this point the channel has been explored by drifting upstream to the Mosher, and high values were found on the northwest rim 15 to 20 feet above the main channel. The north face of gravel at the north end of the pit shows the two gravel members separated by a volcanic member and the whole distinctly faulted. From these workings the channel extends south-southwestward in the Chili Gulch, where later dissection appears to have cut through and obliterated it, though possibly remnants occur along the south side of Chili Gulch farther south. Storms holds that deposits far to the south above the San Andreas road are to be correlated with this channel.

[1] Storms, W. H., Ancient channel system of Calaveras County: Twelfth Ann. Rept. California State Mineralogist, 1894, p. 490.

DURYEA WHITE LEAD.

The Duryea channel, which lies under Stockton Ridge, is characterized by white gravel made up of well-rounded white quartz pebbles and white quartz sand. Its first appearance on the north is on the northern slope of Stockton Hill, on the south bend of the road west from Mokelumne Hill down to Middle Bar Bridge. There, at an elevation of 1,275 feet, the Hexter tunnel has followed this channel in a S. 30° E. direction beneath a capping of rhyolite and andesite that forms the crest of Stockton Ridge. In Chili Gulch, about a mile south of Mokelumne Hill, where the channel appears on the southeast side of the ridge, occurs the best exposure of the gravel characteristic of this channel. Thoroughly rounded quartz gravel 30 to 40 feet in thickness is seen interbedded and cross-bedded with bands of pure, clean washed quartz sand. This is overlain by a massive member made up of compact coarse quartz sand and fine gravel and the whole is capped by rhyolitic tuff. To the south, at the Concentrator mine, where both the Concentrator and Duryea channels appear, this channel, 100 feet wide, carries characteristic gravel 10 to 20 feet in thickness at the base, overlain by 10 to 20 feet of gravel fine capped by a series of rhyolitic tuffs and rhyolites, including the pink rhyolite, and by andesitic tuffs and breccias.

CONCENTRATOR CHANNEL.

On the north slope of Stockton Ridge, about a quarter of a mile southwest of the Hexter tunnel, a hydraulic pit exposes a well-defined channel about 25 feet lower than the Hexter tunnel, which is regarded as the north end of the Concentrator channel. A deposit of mixed gravel 5 to 6 feet thick containing quartz and metamorphic bowlders, but, so far as observed, no volcanic pebbles, has a width at this point of 200 feet and is overlain by a succession of varicolored rhyolitic tuffs about 20 feet thick. On the rim at an elevation of about 50 feet above this channel are well-rounded quartz gravels which probably were laid down by a branch of the Duryea channel system; and overlying both is a thick, massive bed of pink rhyolite. From this point workings show that the channel extends under Stockton Ridge in a direction generally parallel to the Duryea channel for some distance, and then, swinging south, diverges and has been found and extensively worked at the Concentrator mine in Chili Gulch. At this mine 6 feet of gravel occurs on bedrock, about 90 feet below and underneath the Duryea lead, and is overlain by white sand and obscure gray or olive-colored deposits. The channel has been opened at this point by drifting for a distance of 1,300 feet. It has been found to fall to the southeastward 35 feet in a distance of 2,900 feet, or about 65 feet to the mile.

KRAEMER CHANNEL.

Lying to the west of the main group of channels which are traceable in a general southerly course from Mokelumne Hill to Central Hill is a series of gravel deposits extending in a southerly direction from a point in Poorman Gulch east of the Gwin mine. They pass east of Golden Gate Hill in the general direction of Central Hill. The gravel at the Bob Paul pit, which is considered to belong to this channel, though poorly exposed, closely resembles that of the Concentrator channel. It is overlain by a succession of rhyolitic tuffs, clay, and gravel, and finally capped by andesitic gravel. It is not one of the main series and at the time of visit had not proved of special commercial importance.

CHILI GULCH CHANNEL.

The Chili Gulch channel lies within the general area occupied by the present gulch of that name and has been thoroughly proved from a point about a mile south of Mokelumne Hill southward for 3 miles. It presents several interesting features, in that it lies throughout its known course below the level of the present stream, follows an extremely meandering course, and is faulted.

Its north end in this county is uncertain, some observers having correlated it with the Gopher channel and others with short, isolated sections of channels found in the vicinity of

Mokelumne Hill. It is first positively recognized emerging from beneath Stockton Ridge south of the Green Mountain pit, on the southeast side of the creek, in the American shaft, at a depth of 110 feet, at an elevation of 1,175 feet. Passing west beneath the creek bed it has been struck at a point south of the Concentrator pit in the water company's shaft at a depth of 115 feet. About half a mile west the What Cheer shaft is commonly believed to have entered the channel at a depth of about 200 feet. Swinging southward from this point through 90°, the channel is found about half a mile to the south, on the west side of the road, in the Werle shaft, at a depth of 200 feet. From this point it is proved by the Pennsylvania shafts Nos. 1 and 2 and the Pellaton shaft—110, 60, and 45 feet deep, respectively—to pass southeastward under the creek, swing to the south, and then completing the semicircle, pass west again under the creek. Immediately west and at a depth of 45 feet it is cut in the Chappellet shaft, and drifting down the channel from this point for a few hundred yards revealed steeply rising bedrock, probably marking a fault beyond which, it is understood, this channel has never been positively identified.

The gravel at the Werle shaft is dark-blue cemented quartz, and at the Chappellet shaft it is also cemented and carries rhyolite fragments; at the America, What Cheer, Werle, and Chappellet workings this is overlain by rhyolitic tuff. The position of the gravel shows the channel to be of inter-volcanic age and the apparent relation of its capping of rhyolite to other neighboring channels tends to indicate that the Chili Gulch channel is the youngest of the main channels of this entire system.

Its grade could not be reliably determined, but it is clear that the bedrock channel now has a very irregular grade, as might reasonably be expected for a late volcanic channel—higher toward the head, moderate along its middle course, and reversed at the south end. Cutting the rich leads under Stockton Ridge and all channels in its path, it has robbed them of some of their values and, reconcentrating them, afforded high returns. It is thus quite natural that the channel should have early attracted attention and now be practically worked out.

The southward extension of these channels approaches Central Hill, and the correlation of several gravel deposits which have been drifted and hydraulicked there is rather doubtful.

AGE OF MOKELUMNE HILL CHANNELS.

It is difficult to give a connected summary of the relative age of all the channels of the Mokelumne Hill system. It is clear at any rate that the main stream of prerhyolitic age is represented by the deep blue lead, and the Tunnel Ridge channel appears to be on a bench of this stream. The Concentrator channel, of which the Duryea channel seems to represent a swinging bench, belongs to the same period and is a tributary coming down from the vicinity of Jackson, in Amador County. The Chili Gulch channel represents the main interrhyolitic channel and cuts the others. The interandesitic channels seem to be of little importance in this system.

CENTRAL HILL AND WESTWARD.

In the Central Hill area, as previously mentioned, the two systems, the Central Hill channel from the southeast and the Mokelumne Hill channel from the north, unite and the stream continued toward Valley Springs underneath the gravel and tuff. Although the connection could not be observed owing to the inaccessibility of most of the workings, and although many details necessarily remain unproved, it seems certain that they do join here and continue westward as one channel. The San Andreas system (Central Hill and Fort Mountain) is believed to enter at the south end of the hill, in the area explored by the Swanson tunnel, and to extend northwest, as shown by the Union shaft in which, at a depth of 150 feet, a 1,200-foot drift extends northward in the channel. The same relation is also indicated by the Palmer shaft immediately beyond which goes down to southwestward sloping bedrock at a depth of 290 feet. The Agostini shaft, half a mile northwest, with slopes turned at a depth of 190 feet, one to the east 150 feet in length, and a deeper one on the west 70 feet in length, suggests that this tributary

turns westward just before reaching this shaft. About 1½ miles to the north the Lava shaft and a long tunnel are commonly regarded as demonstrating the location of the channel from the Mokelumne Hill area on its southward course. This channel should thus unite with that from the northeast in the vicinity of the Agostini shaft. The Putnam and Pump shafts, 1¼ and 1½ miles to the south, respectively, indicate the position of a swing of the combined channel.

West of Central Hill the channel rims have been only slightly explored. The Horsewell shaft, after penetrating mixed gravels of quartz, bedrock, and sand, encountered at a depth of about 300 feet dark-blue gravel. On the Spring Valley property two shafts, one 176 feet and the other 167 feet deep, appear from the dumps to have cut mixed gravels with some quartz and rhyolite, and are reported to have discovered at the bottom a thin cemented auriferous gravel. On the Shaw property a shaft sunk through gravel for 150 feet failed to reach bedrock, and a tunnel 500 to 600 feet long has also been run at that point beneath a cap of rhyolite.

FORT MOUNTAIN CHANNEL.

In Tertiary time a broad depression extended north and south on the middle slopes in Calaveras County between the first ridges of the Calaveras formation now dissected by Esperanza and Jesus Maria creeks and the higher slate ridges of the Blue Mountains farther to the east. This depression was occupied by a southward-trending branch of the Tertiary Calaveras River, now called the Fort Mountain channel. It headed a few miles east of West Point, south of Devils Nose, the high point overlooking Mokelumne River; possibly its extreme headwaters lie a few miles farther east, in a sharp lava-filled depression just east of Devils Nose, but it did not connect with the Tertiary Mokelumne mentioned on a preceding page. It continued southward for about 15 miles to a point a few miles southwest of Sheep Ranch; turning to the southwest, it then continued for a few miles and joined the main Tertiary Calaveras River (Central Hill channel) about 4 miles southeast of San Andreas. Across the Middle and South forks of Mokelumne River much of the channel is eroded. Between Calaveras Valley and Sheep Ranch a large part of the channel remains and has been mined only in part. From Sheep Ranch to the junction with the master stream only a few gravel patches remain to indicate its direction.

The gravel filling the deepest gutters of the channel is subangular, is partly cemented, and contains, at least in places, pebbles of rhyolite. The width is rarely over 100 feet.

The old valley was first filled with rhyolitic tuffs, the exposures of which will indicate its general direction. This tuff attains in places a thickness of 300 to 400 feet.[1] The origin of this rhyolite is somewhat doubtful; possibly it was erupted from some local vent near the head of the channel. The rhyolites are covered by andesitic tuffs with a greatest thickness of 700 feet, but it is not probable that these flows reached the summit of the western divide of the Fort Mountain Valley.

The grade has the gentle slope characteristic of the longitudinal channels. The first exposures on Hunter Creek, 4 miles south-southwest of Devils Nose, have an elevation of 3,500 feet. At Railroad Flat the elevation is 2,500 feet; Esperanza Creek just fails to cut through the channel to the bottom. It is likely that some local faulting has taken place where the channel crosses the South Fork of Mokelumne River. Jesus Maria Creek just trenches the gutter at an elevation of about 2,300 feet. Near Sheep Ranch the elevation is about 2,150 feet, and at the junction with the Central Hill channel it is about 1,100 feet. From Esperanza Creek to Sheep Ranch the grade in 5 miles is about 70 feet to the mile in a southerly direction; from Sheep Ranch to the junction the grade increases to 100 feet to the mile, corresponding to a southwesterly stream course.

No quartz mines of importance have been developed along the upper part of the Fort Mountain channel, but the slates in many places contain seams of gold-bearing quartz which have yielded the gold now concentrated in the channels. Near Sheep Ranch, however, are some well-known quartz mines which have attained considerable depth. The extensive gravels about Railroad Flat are mostly subangular and mixed with red soil. Turner regards them as perhaps derived by local disintegration on the Tertiary surface and says that they lie somewhat

[1] Big Trees folio (No. 51), Geol. Atlas U. S., U. S. Geol. Survey, 1898.

higher than the wash gravels with rhyolite pebbles which are exposed about a mile farther north. The Lampson channel, 2 miles south of Railroad Flat, forms a small westerly tributary to the main Fort Mountain channel.

The main channel has been mined at Hunter Creek, 3½ miles northeast of Woodcock's mill; here the stream gravels as exposed by a hydraulic cut are 30 feet thick, contain pebbles of rhyolite, and lie under a rhyolite capping which appears to extend north under the andesite. The Fort Mountain channel has further been mined east of Railroad Flat, on Esperanza Creek, where a shaft is sunk about 100 feet to bedrock, and at the Banner Blue Gravel mine, on Jesus Maria Creek, worked by a shaft sunk 63 feet deep through the rhyolite. The gravel is about 100 feet wide, carries from 25 to 40 per cent of coarse bowlders, and contains much black sand and iron sulphide. A thickness of 6 to 8 feet of gravel is exhibited, which is said to contain from $3 to $4 a ton and is mined and milled for $1 to $1.25 a ton.[1]

Near Sheep Ranch are several gravel areas, capped by rhyolite; some of these have been mined by the hydraulic process, and the bottom gravel drifted in places. At the Brassila mine, on the same channel 2 miles northwest of Sheep Ranch, the gravel body is about half a mile wide. The channel is mined by drifting, and the cemented gravel is crushed and amalgamated in a 10-stamp mill. Drifting operations have also been carried on at the Lava Bed mine through a shaft 85 feet in depth; the partly cemented high-grade gravel has been followed for several hundred feet and is crushed and amalgamated in a 5-stamp mill.[1] At least a mile of the rhyolite-capped channel remained unworked in 1902. The channel is thought to be 150 to 200 feet wide and covered by 24 feet of gravel and sand. The gravel is coarse, subangular, and poorly assorted. Tests are said to have given an average value for the entire thickness of 50 cents a cubic yard.

The lower part of the Fort Mountain channel from Sheep Ranch to Calaveritas is largely eroded away, although a few gravel patches mark its southwest direction very clearly; in the main it followed O'Neils and San Antonio creeks. There are indications that it was joined near Cave City by a tributary from the northwest by way of Eldorado or Mountain Ranch.

To the west between Mountain Ranch and Cave City three areas of gravel have been worked. One is a mile northwest of Cave City at the Austrian Hill mine, where a shaft penetrated two volcanic beds and two gravel beds. A mile to the northwest the Gascon Hill pit shows a deep, steep-sided channel with at most 25 feet of gold-bearing gravel capped by rhyolitic tuff, which in turn is overlain by gravel. Nearby a pit 200 by 200 feet shows a surface of slate bedrock marked by a channel 200 feet in width to a depth of 15 feet, bearing 5 feet of subangular gravel, mainly quartzite. The principal gravel mining in this vicinity, however, at the time of visit was in Eldorado Gulch, a mile west-southwest of Mountain Ranch, on the Rose Hill property. Here hydraulic operations were in progress in 1901 and 1902. On the Rose Hill property hydraulic work has revealed a channel extending for a distance of 800 to 1,000 feet, 100 to 150 feet wide in a N. 75° E. direction. In the Emery pit on this property the face at the head of the pit shows the channel to be filled to a depth of 50 feet with the following beds:

Section in Emery pit, near Mountain Ranch.

	Feet.
Upper gravel topped by soil	5
Rhyolitic tuff eroded at upper surface	5
Gravel with large rhyolitic pebbles in base	5–15
Rhyolitic tuff (cut out locally on the east rim and tongues of tuff intercalated in gravel)	0–15
Reddish angular slate gravel grading upward into fine clay cement with fine pebbles	8
Gold-bearing cemented gravel	7–8

The gravel consists of coarse and angular slate fragments with rounded pebbles of quartz, quartzite, and other bedrock. All the gravel members except the lowest contain identifiable rhyolite pebbles, but no andesite was recognized. The shingling of the gravels clearly indicates a northeast direction of flow of the depositing stream. It is probable that this stream was a tributary to the main channel. The recovery averaged 37 cents to the yard during the first

[1] Kerr, M. B., Mining resources of Calaveras County, published by Calaveras County Exhibit, Mining Fair, San Francisco, 1898.

year; subsequent operations have netted somewhat lower values. It was stated in the press that in 1902 one-third of an acre had yielded $5,358.

About 3 miles to the southwest, in the vicinity of the settlement of Old Gulch, several areas of gravels belonging to this channel occur. One-quarter of a mile southwest of the forks, at the road leading from the Old Gulch road to Dogtown, the road follows the channel, here 150 to 200 feet wide and littered with large rounded bowlders of quartz and slate; between the forks of the road, in the elbow of the stream, the channel widens to 300 feet. Immediately to the south the channel narrows and a succession of rapids appear, the width decreasing at one point to 50 or 60 feet.

In the Rocchi pit hydraulicking has exposed a stretch of 800 feet of this channel, 60 to 80 feet wide and carrying a bed of 60 to 75 feet of rather fine mixed gravel. The pebbles are of quartz and metamorphic rocks and are rather more rounded than those near Mountain Ranch. Thin lenses of rhyolitic tuff are included in the sections exposed. The grade of the bedrock and the shingling of the pebbles indicate that at this point the stream flowed toward the south. A small patch of gravel about a mile farther west has been hydraulicked. Just west of that this channel has apparently united with the master stream, the Central Hill channel.

COLUMBIA BASIN.

The vicinity of Columbia is of exceptional interest to the placer miner and to the geologist. The former found here in a flat valley underlain by limestone (Pl. XI, *A*, p. 72) one of the richest districts in the Sierra Nevada. It is said that over $50,000,000 was taken out from the Columbia diggings from 1853 to 1870, and some work is going on even at the present time. In 1901, when the locality was visited, some of the gravel in the limestone potholes was being worked and very rich ground had recently been drifted on the Dondero claim at Yankee Hill, 2 miles east of Columbia.

To the geologist the Columbia basin is of interest, as a Tertiary valley has here been accidentally preserved with almost the same topographic features which it possessed in prevolcanic time. A number of bones of extinct animals have been found in its gravels as described by Whitney,[1] among them those of the mastodon, elephant, and *Equus excelsus*. Human implements have also been found, but all of these occurrences are of doubtful value, for the valley has been as open in Quaternary as in Tertiary time and the distinction of the different gravels is not easy.

The Columbia basin is a flat, open valley about 2 miles in diameter, at an elevation of about 2,100 feet, just to the east of and 1,000 feet above the canyon of the Stanislaus. Low hills at most 200 feet in height separate it from the steep slopes of the modern canyon, while on the east a low ridge separates it from the Yankee Hill basin. To the north of Columbia the hills rise 500 feet above the town and increase rapidly in height toward the east, so that Yankee Hill is inclosed by steep ridges rising over 1,000 feet above the flat. The Columbia basin is now drained by Mormon Creek toward the south and into the Stanislaus; Yankee Hill is drained by Woods Creek, which flows south past Sonora into the Tuolumne. Both creeks flow in flat trenches cutting through a series of low hills; this southward drainage was evidently effected in Quaternary time. During the andesitic epoch of the late Tertiary the valley drained southward by way of the Table Mountain channel. On the other hand, in prevolcanic Tertiary time the drainage was evidently northward by Gold Spring toward some point of the deep channel of the Tertiary Calaveras River near Douglas Flat. The stream headed at the amphitheater of Yankee Hill, flowed southward for a couple of miles, then turning north passed Columbia and crossed the present course of the Stanislaus Canyon.

A broad belt of crystalline limestone occupies the center of the Columbia basin from north to south. On each side of the belt are ridges of the Calaveras formation; they seem to have been particularly resistant on the east of Yankee Hill. The valley lies between two areas of granodiorite intrusive into the slates and in this separating strip, which is a few miles wide, a

[1] Auriferous gravels, pp. 256, 257, 283.

great number of narrow but extremely rich "pocket veins" have been formed. The slow degradation of this area during prevolcanic time concentrated the coarse gold to an extraordinary degree in the flat central basin; deep potholes corroded in the limestone proved to be exceptionally effective gold riffles. Toward the close of the Tertiary period the valley was covered by andesite and rhyolite tuff, of which some small areas remain; of the former near Springfield, of the latter near Columbia and Gold Spring. Gradual erosion of this cover took place in Quaternary time, and as soon as this mantle was removed the process of gold concentration again began.

The miners recognize the presence of a Tertiary channel in this valley, besides much Quaternary wash. They trace it upstream from Gold Spring to a point west of Columbia, thence southward to a point on the low ridge separating Mormon Creek from Woods Creek, thence up Woods Creek to Yankee Hill. The elevation of the bedrock at Gold Spring is 2,150 feet and at Columbia about the same. Northwest of Browns Flat it is 2,200 feet and at Yankee Hill 2,260 feet. The grade of the channel was evidently very slight.

All the gravels of the Columbia region are imperfectly washed and at Yankee Hill the wash becomes subangular. At the Dondero mine, Yankee Hill, the deep channels, which here split up into several tributaries, lie below the surface of the creek in narrow troughs. One of these recently drifted by Mr. Dondero yielded $50,000 in coarse gold within a short distance and was opened by means of a tunnel on a 3 per cent grade, nearly a mile long. This channel contained rough gravel 20 feet wide between very decomposed rims of calcareous slate; the trough above was filled with barren gravel and brown muck.

A study of the surroundings of Columbia is recommended for those who still believe that the prevolcanic Tertiary surface of the Sierra Nevada was a peneplain.

CHAPTER 20. THE SONORA AND YOSEMITE QUADRANGLES.

GENERAL FEATURES.

The Sonora and Yosemite quadrangles lie to the south and southeast of the Big Trees quadrangle. They embrace a rectangular area of about 35 by 54 miles which contains a considerable part of the foothills and middle slopes of the Sierra in Tuolumne and Mariposa counties. This area is drained by Tuolumne and Merced rivers, which break across the greenstone ridges of the foothills in rough canyons. The region is very similar to the Jackson and Big Trees quadrangles described in chapter 19.

GEOLOGY.

The southwest corner of the Sonora quadrangle is occupied by the Ione formation and the Quaternary gravels of the valley. Next follows a broad foothill belt of high greenstone ridges which contain several strips of the Mariposa formation (Jurassic). The northeastern half of the Sonora quadrangle and the southwest corner of the Yosemite quadrangle are occupied by the slates and limestones of the Calaveras formation (Carboniferous) intruded by several bosses of granodiorite. Granites and granodiorites make up nearly the whole of the Yosemite quadrangle. South and southeast of Merced Falls are two level-topped buttes capped by sandstone of the Tejon formation, which rests almost horizontally upon the nearly vertical edges of the Mariposa formation. The basal bed is crowded with angular fragments of the slate and with abundant pebbles of white vein quartz; the upper beds are composed of a light-colored quartzose sandstone with numerous bands of small quartz pebbles. Marine fossils (*Venericardia planicosta*) are fairly abundant in the upper bed at the west end of the butte that lies 1 mile south of Merced Falls. These sandstones are overlain to the west by the light-colored sandstones of the Ione formation. The two formations are probably not absolutely conformable, as the Ione beds transgress upon the rocks of the "Bedrock series" farther north.

The rocks referred to the Ione formation in the Sonora quadrangle are a series of soft, usually light-colored, more or less tuffaceous beds which overlap the Eocene sandstones and the older rocks of the "Bedrock series" in the southwestern portion of the quadrangle. The beds are apparently horizontal but dip slightly to the west. They exhibit considerable lithologic variety. Some of the beds are composed of a light-colored, fairly quartzose sandstone; others are stained brown or yellow with iron oxide, or striped with yellow, brown, or pink bands in fine wavy patterns; still others are composed of fine white rhyolite tuff and of the decomposed tuff called clay rock. The more quartzose beds occur near the base of the series.

Overlying the Ione formation in the southwest corner of the Sonora quadrangle is a series of sandstones and conglomerates which contain varying amounts of andesitic detritus.

Andesitic tuff of the type so abundant over large portions of the Sierra Nevada occurs but sparingly in the Sonora quadrangle, being confined to the vicinity of Montezuma, Soulsbyville, and the northeast corner of the quadrangle.

The entire area of these quadrangles has acted as a solid crust block which has been tilted with the rest of the Sierra. Only a few minor faults and dislocations are present.

TUOLUMNE TABLE MOUNTAIN.

The Oroville Table Mountain on the north and the Tuolumne Table Mountain on the south have long been places of exceptional interest both for the miner and the geologist. The lava cap of the Oroville Mountain represents one of the earliest of the Tertiary eruptions, but the basaltic flow of Tuolumne County took place toward the close of the volcanic epoch.

During a lull in the eruptions of fragmental andesitic material, when the Tertiary river channels were already choked by volcanic débris and the low divides were covered a new drainage line was established which took the transverse direction of the modern canyons. This new drainage line began in the Dardanelles quadrangle, entered the Big Trees quadrangle just east of Clover Meadow, and continued thence in a general southwesterly direction by way of the Calaveras grove of big trees down to Douglas Flat, where it encountered one of the principal Tertiary valleys, now filled with rhyolitic and andesitic lavas. The new drainage did not continue along the old stream toward San Andreas, but turned south, crossed the present line of the North Fork of the Stanislaus at Squaw Hollow, and continued down the west bank of this river to Parrott Ferry. Turning southeastward at the latter point, it again crossed what is now the Stanislaus Canyon and continued on to Shaws Flat and thence southwest across the Sonora quadrangle to Knights Ferry. This channel is known to miners as the Table Mountain channel. The stream was a long one, holding much the same relation to the Neocene slope that the Stanislaus, with its North and Middle Forks, holds to the present general drainage system.

This new channel was actively eroded for some time and cut a rather narrow V-shaped trench through the earlier volcanic rocks and on the lower slopes of the range, also down into the "Bedrock series," in places to a depth of several hundred feet. A small amount of gravels accumulated in the bottom of the channel. Renewed eruptions filled the valley with andesitic sands and tuffs, and finally the channel was sealed by a flow of black basaltic rock which followed it all the way from the Dardanelles quadrangle down to Knights Ferry, on the Stanislaus. As may be seen in the Big Trees and Sonora quadrangles, remnants of this flow are preserved high up on the divides along the Stanislaus at elevations 1,500 feet above thepresent stream on the middle slopes, thence gradually sinking relatively to the modern drainage level until, at a point a few miles above Knights Ferry, the bottom of its channel is on a level with the stream bed of the modern canyon.

That part of the flow which is designated Tuolumne Table Mountain, and which is of importance from the miner's standpoint, is almost continuous from Shaws Flat by Sonora and thence down to Knights Ferry—a distance of about 20 miles. The thickness of the lava flow is at most 200 to 300 feet.

Although the rock has all the external characteristics of a black fine-grained basalt, locally with columnar structure, it is in reality a latite. It has a high percentage of total alkalies, with potash slightly in excess of soda. Chemically it stands between the andesites and the trachytes. Mineralogically it consists of labradorite, augite, olivine, magnetite, and a glass rich in potash. Further notes on this rock and on its distribution may be found in the Sonora and Big Trees folios.[1] The pay channel is of irregular width, rarely exceeding 100 feet; in many places there are two channels at somewhat differing elevations. The rims rise sharply 100 or 150 feet above the bottom. The gold is coarse and the gravels are thin, andesitic tuffs here and there closing down on the bedrock. The gravel is as a rule covered by a few feet of clay and 50 to 70 feet of sands of volcanic origin. Above this lies at many places a compact andesitic tuff, which is succeeded by the solid latite, from 50 to 200 feet in thickness.

The channel has been worked by a number of tunnels and inclines, chiefly between Shaws Flat, near Columbia, and Montezuma—a distance of about 10 miles. The gravels have proved to be very spotted in value, and Whitney[2] points out that as a whole the operations have been unprofitable. Most of the drift mining was undertaken between 1855 and 1865. In 1870 mining operations were suspended, but some work has been in progress intermittently almost every year since then. In 1902 a little work went on near Springfield and also at the Leap Year tunnel, 1½ miles below the Alabama quartz mine. Probably not more than $1,000,000 has been extracted from the gravels underneath Table Mountain.

About Douglas Flat and elsewhere north of the Stanislaus there is no evidence that this channel had trenched the bedrock below the earlier andesitic and rhyolitic tuffs. Nor is there

[1] Nos. 41 and 51, Geol. Atlas U. S.

[2] Auriferous gravels, p. 134.

indication of any gravel channel below Table Mountain where it commences south of the river overlooking and 1,000 feet above Parrott Ferry. The first appearance of the channel is 1 mile southwest of Columbia, near Springfield, at the Davis place. There is an andesite hill rising 100 feet above the Columbia Valley and the channel begins in the flat a quarter of a mile north of the base of this hill and continues underneath it, 30 to 40 feet wide, with 2 to 3 feet of imperfectly washed gravel. It seems thus that the Table Mountain channel had its origin in the Columbia Valley, the streams of which, in prevolcanic time, most probably drained northward toward Douglas Flat. At some time, however, it must have connected with the Cataract channel, in the Big Trees quadrangle, also an interandesitic channel and followed by the same flow of latite.

At the south end of the Davis ground a shaft has been sunk to a depth of 160 feet through gravel, sand, and andesitic tuff. The channel was found, but the water proved too abundant to handle. South of this point the channel continues but has not been mined. In 1901 some drifting was in progress on the Richards ground, on a tributary to the main channel. The elevation of the bedrock is 2,080 feet at the inlet and 2,020 feet at the Davis shaft.

The channel crosses Mormon Creek among deep potholes in limestone. From this point for a few miles southwest the eastern rim of the old valley is preserved and rises 100 to 200 feet above the flat surface of the Table Mountain. But the west side is deeply eroded and here the channel has been opened by a number of tunnels, described and figured by Whitney [1] as the Buckeye, Boston, Maine Boys, and Eureka tunnels.

From a point northwest of Jamestown for a few miles to the southwest both rims of the channel are eroded and the volcanic cap rises abruptly with its black escarpments and level top, the width of which is from a few hundred feet to half a mile. Several tunnels have been driven to the channel, and, as stated above, work was in progress in 1901 on the Leap Year claim, extending for 1,300 feet along the ridge, 1 mile below the Alabama mine, where Table Mountain crosses the Mother Lode. A higher tunnel has been opened on an upper channel (elevation, 1,660 feet), with a thin gravel deposit of quartz, greenstone, and siliceous slates covered by gray pipe clay. This in turn is overlain by a brown, extremely well-stratified volcanic tuff. A lower tunnel, at an elevation of 1,620 feet, was intended to open the main channel, which is reported to be up to 300 feet wide, with gravel 3 to 5 feet deep.

At Montezuma a considerable body of rich quartz gravel has been mined. This gravel probably belongs to an older Tertiary stream. Southwest of Montezuma the Table Mountain flow enters a belt of higher serpentine and greenstone ridges, and from this place down to Knights Ferry, which is outside of the Sonora quadrangle, the old valley is preserved, both rims as a rule rising above the lava. Naturally, little mining has been done, as the channel could not readily be drained. It is said that the channel has been opened 6 miles above Knights Ferry by tunnels 50 to 100 feet above Stanislaus River. The gravel is reported to have been 10 to 15 feet thick, with "pay in spots." Gray "cement" covers the gravels.

Knights Ferry is situated at an elevation of about 200 feet on the north side of the Stanislaus, where the river debouches with steep grade from a rocky canyon into the rolling foothill country. The last ridges of the "Bedrock series" at the edge of the valley dip rather sharply underneath a series of well-stratified brown and gray andesite tuffs, which rise 200 feet above the river and are gently inclined westward. These tuffs are covered by thin Quaternary gravel of siliceous pebbles and the wide valley of the river between the bluffs and the first bedrock hills contains several Quaternary gravel benches 170, 100, and 35 feet above the water; many of these have been mined.

The last outcrops of the Table Mountain latite appear on the south side of the river, a short distance above the bridge at Knights Ferry. The top of the flow, which, as exposed on the slope of the south side of the canyon, is 60 feet thick, lies about 150 feet above the river and is 1,500 feet wide. The channel itself is not exposed, but the gradient of its slope would carry it underneath the separating Quaternary gravels and underneath the bluffs of andesitic sandstone a little farther west.

[1] Auriferous gravels, pp. 134-137.

The latite flow does not stand out as a table mountain in these most westerly foothills. On the contrary, the old valley may be clearly seen from any prominent point, the bedrock hills rising gently on the south above the volcanic flows to heights of 500 feet or more, while on the north the Bear Mountains, some distance away, rise to elevations of 3,000 feet.

Two miles above Knights Ferry the Table Mountain flow crosses the canyon of the Stanislaus. The top of the flow is approximately 200 feet above the river, 1,500 feet wide, and 150 feet thick. Sliding débris obscures the relations below, but the basaltic rock is probably underlain by andesite tuff or sands 100 feet thick. The bedrock of the old channel is somewhat below river level. No mining has been done here. The canyon of the Stanislaus begins immediately east of Knights Ferry, and the first 2 miles of it are cut first in granitic rocks, then in greenstones. The river grade is very steep but becomes more gentle above the crossing of the Table Mountain channel.

GOLD-BEARING AREAS.

The lower foothill ridges of these two quadrangles, composed of greenstones and Mariposa formation, contain few gold quartz veins. The veins of the Mother Lode traverse the Sonora quadrangle diagonally from northwest to southeast, and many prominent mines are located along them, from the Rawhide, App, and others on the north to the Princeton on the south. The vicinity of Sonora and Tuttletown is distinguished by the occurrence of many small and rich pocket veins.

The slates of the Calaveras formation on the east of the Mother Lode are here relatively rich in gold-quartz veins. Possibly this is due to a number of small granitic intrusions contained in the slates in the Sonora quadrangle. Among these are the Soulsbyville veins in the granodiorite a few miles east of Sonora and the Bigoak Flat veins, 12 miles south-southeast of Sonora; still farther east are the Buchanan veins and those in the southwestern part of the Yosemite quadrangle, which otherwise is almost barren of gold deposits. The gold-bearing areas of the Yosemite quadrangle are practically coextensive with the area of the Calaveras formation. The more productive mines are located along a line from the Kinsley mining district on the western border of the quadrangle to the Hite Cove region, in a course about S. 60° E. This belt is frequently referred to as the East lode and continues into the Sonora quadrangle, but it is rather a zone of disconnected short veins with widely differing strike. The mines of the Mother Lode situated in this area have yielded several million dollars, but a considerably larger amount, said to be $18,000,000,[1] has been extracted from the quartz of the mines east of the Mother Lode. Soulsbyville has been the most productive locality.

Tertiary gravels are very sparingly represented. They are confined to those below Table Mountain, which have never proved very remunerative; to those of a small area at Chinese Camp, which were rich; and to the gravels west and northeast of Colfax Gate, in the Sonora quadrangle and the adjoining part of the Yosemite quadrangle. With this exception the Yosemite quadrangle contains no Tertiary gravels of importance.

On the crest of the plateau-like ridge a few miles east of Groveland, overlooking the deep canyon of Tuolumne River, are some considerable bodies of river gravel, doubtless representing the Neocene Tuolumne River. These have been hydraulicked at several points, giving good exposures of the deposits. The area 3 miles west of Colfax Gate, which occupies about 200 acres, is made up chiefly of pebbles of siliceous rocks of the Calaveras formation and of quartz. The deposit is 100 feet or more in thickness. The gravel bank at the mine 1¾ miles due north of Smith Station contains pebbles of black siliceous argillite, and also of rhyolite, the latter being common. A third area, which also has been mined, is located 2 miles farther west-northwest. All the gravel areas of this ancient river representing the present Tuolumne appear to have been covered with andesitic breccia. What is probably a part of the same river deposit occurs 3½ miles northeast of Colfax Gate, at the edge of the Sonora quadrangle, and extends eastward into the Yosemite quadrangle. On the west side of Moore Creek is a small well-defined channel that has been traced for about 2 miles. Its elevation is less than that of the larger channel just described, and it is probably later in age.

[1] California mines and minerals, published by the California Miners' Association, San Francisco, 1899, p. 354.

The production from the Tertiary gravels of this area is small. Three or four million dollars would probably cover the entire output, most of which came from Table Mountain, Montezuma, and Chinese Camp. The gravels in the eastern part of the Sonora quadrangle appear to be of lower grade. In 1908 drift and surface mines yielded only $12,395. In contrast to this the Quaternary gravels worked in the early days yielded phenomenal sums. An estimate [1] of the early placer output of the camps in Tuolumne County aggregates $100,000,000, aside from $55,000,000 asserted to have been derived from the Tertiary and Quaternary gravels of Columbia (in the Big Trees quadrangle). Most of this wealth came from the northwest corner of the Sonora quadrangle, and, of course, to a large extent it represents Quaternary reconcentration of Tertiary gravels carried away by erosion. The gold was unusually coarse, many nuggets weighing from 20 to 75 pounds being reported from the vicinity of Sonora.

Quaternary gravels have been worked on a large scale at Lagrange, near the place where Tuolumne River issues from the mountains.

The present production from the placer mines is very small and is derived mainly from the vicinity of Jamestown and Table Mountain.

TERTIARY TOPOGRAPHY.

Only one of the Tertiary rivers, the equivalent of the present Tuolumne River, can be traced across this area. One striking fact is that the present Tuolumne follows closely, except in its lower course, the valley of the Tertiary river. This is due to the small amount of andesitic lavas, which simply followed the old valley downward without flooding the divides or causing important stream diversion. South of the Tertiary Tuolumne the lavas are practically absent and the most important guide to the locating of the Tertiary watercourses fails. H. W. Turner [2] has established the course of the Tertiary Tuolumne across the Yosemite and Sonora quadrangles. His statement is as follows:

> In the Yosemite quadrangle only one of the Neocene streams, the Tuolumne, can be traced by its gravels. The reason of this is that only in the Tuolumne basin were there extensive lava flows, which filled the Neocene drainage and preserved the gravels underneath. Even here the gravels and overlying lavas have been largely eroded.
>
> The Neocene channel can be traced from the ridge east of Piute Creek, westward to a point north of Rancheria Mountain, thence down Deep Canyon, from which point it may have gone down Rancheria Creek or over through what is now Tiltill Valley, thence over the site of the Hetch Hetchy, reaching the south side of the present Tuolumne Canyon to the west of Hog Ranch. The bench, with an altitude of about 8,000 feet to the east of Rodgers Canyon, pretty certainly represents a portion of the Neocene Tuolumne basin, but except near Rodgers Creek the lava covering has been entirely removed.
>
> Going west we find the lava covering well preserved on the spur east of Piute Creek, but no gravels are exposed, but the V-shaped channel is clearly evident on the slope toward Piute Creek. To the west of this creek is an even better section of a lava-filled V-shaped channel, and in this case the river gravels are to be seen perhaps 50 feet in thickness at the bottom of the channel. A short tunnel was run in here many years ago, presumably for placer gold in the gravel. Besides abundant lava pebbles, there are numerous pebbles of slate and metamorphic lavas such as make up the mass of Mount Dana, and one pebble was found of epidotiferous sandstone, precisely like the rock of the summit of Dana.
>
> [Plate XXVIII shows the deep trough (at Piute Creek) of the Tertiary Tuolumne River exposed by the canyons of the present day.]
>
> Since between this locality and Mount Dana the bedrock series is all granite, it appears probable that in Tertiary time, as now, the Tuolumne River headed near Mount Dana. Where Rancheria Creek runs through Deep Canyon it has but a slight grade, which is probably nearly the grade of the Neocene Tuolumne, which formerly passed through it. The water for considerable stretches is quite still late in summer, when the flow is small.
>
> Although none of the gravels or the lavas of the Neocene Tuolumne basin are to be found between Rancheria Mountain and a point north of Poopenaut Valley, nevertheless the approximate course of the channel is not a matter of doubt.
>
> The configuration of the country is such that the river must, as before noted, have either gone down Rancheria Creek or over the site of Tiltill Valley, thence westward over the site of the Hetch Hetchy. The lava patches on the ridge north of Poopenaut Valley are presumed to rest on a portion of the slope of the Neocene Tuolumne basin, and the same is true of the lava area 3 miles west of Poopenaut Valley, and the gentle slopes of the ridge in this vicinity are doubtless a portion of the same basin. The next point where the lavas are preserved is about 4 miles westerly from Hog Ranch. From there still farther westward there are other lava patches, some of them capping river gravels.
>
> On Rancheria Mountain, resting on andesite tuff, and apparently capped by the compact lava (latite) adjoining, is some gravel containing pebbles of augite andesite, pegmatite, quartz. This evidently represents a stream of the volcanic period, and later in age than the gravels above described.

[1] California mines and minerals, published by the California Miners' Association, San Francisco, 1899.
[2] Post-Tertiary elevation of the Sierra Nevada: Bull. Geol. Soc. America, vol. 13, 1901, pp. 540-541.

CHANNEL OF TERTIARY TUOLUMNE RIVER, EXPOSED BY EROSION OF PRESENT RIVER ON WEST SIDE OF PIUTE CANYON, TUOLUMNE COUNTY.

Channel filled with andesitic tuff-breccia. Photograph by H. W. Turner. See page 218.

The most western point where the gravels of the Neocene Tuolumne have been preserved is east of the head of Big Humbug Creek, in the Sonora quadrangle, and the most eastern Piute Canyon. If now we calculate the average grade of the Tertiary stream between these two points and the average grade of the present river between the same points, we can compare the grades of the two streams. The altitude of the Neocene Tuolumne gravels at Big Humbug Creek is about 2,800 feet, and at Piute Canyon 7,500 feet, giving a difference of 4,700 feet. The altitude of the present Tuolumne north of Big Humbug Creek is 1,500 feet, and at Pate Valley, at the mouth of Piute Creek, 4,550, giving a difference of 3,050 feet. The horizontal distance between the two points is about 33 miles.

Assuming that both the Neocene and the present streams took a direct course, we have a grade of 142 feet to the mile for the Neocene channel and a grade of 92 feet to the mile for the present channel. While the Neocene river occupied a rugged canyon, nevertheless this canyon was much less deep and rugged than that of the present Tuolumne, which implies, other things being equal, a higher grade for the present than for the Neocene channel, while, as we have seen, the reverse is the case. The broad channels and large sand and gravel deposits of the Neocene streams of the Sierra farther north can scarcely be explained on any other hypothesis than of comparatively gentle grades indicating an old age for the streams, and this must have been likewise true of the Neocene Tuolumne, although in less degree.

Assuming that the Neocene Tuolumne had originally a grade at least as low as that of the modern stream, which is evidently yet a young stream, it is clear that the present grade of the Neocene channel must have been brought about by a differential uplift on the east, resulting in a tilting of the range westward.

To the facts given by Turner should be added that the course of the Tertiary river from Piute Creek to the Dorsey mine, a distance of 32 miles along the probable curves of the old river, is west-southwest and the grade would be, computed in this manner, 136 feet to the mile. From the Dorsey mine the direction changes to west-northwest, and the grade for 7 miles averages only 47 feet to the mile, thus strengthening further the argument for the tilting movement.

From the last gravel patches on Big Humbug Creek the general direction seems to have been westward, between Hog Mountain and Algerine, and thence to Chinese Camp. If the quartz gravels at Chinese Camp are assumed to indicate the position of the channel, there is an average grade of 90 feet to the mile in this, the lowest part of the course.

So far as the presence of lavas and gravels permits us to trace the Tertiary surface of the Sierra in this area it is of essentially the same kind as in the Jackson and Big Trees quadrangles. A similar belt of rough and prominent greenstone ridges constitutes the foothills, rising abruptly about 500 feet above the rolling plains of the Ione formation as south of Lagrange, or above a flat basement of truncated Mariposa formation as at Merced Falls. The latter locality is of especial interest, for we have here both north and south of Merced River several small patches of sandstones of the Tejon formation (Eocene), containing marine fossils, resting on this basement with gentle westward dip at the very foot of the first greenstone ridges. The Tejon reaches up to elevations of 800 feet from the basement, which has an elevation of 500 feet and is less than 200 feet above the present river bed as it emerges from the "Bedrock series." This shows very plainly that the relief of the foothills in Eocene time differed but little from that in the Neocene or late Tertiary period.

The general evidence is clearly to the effect that the high ridges of Moccasin Peak, Penon Blanco, and Bullion Mountain, now attaining elevations of 3,000 to 4,000 feet, were as prominent in the Tertiary period as at present. Eastward from these ridges the general surface was lower, but still farther to the east and northeast there rose a series of high hills, corresponding to masses of slates of the Calaveras formation projecting into the main granite mass of the Sierra. The best example of these is found in the northeastern part of the Sonora quadrangle, west of the Middle Fork of the Tuolumne. The Tertiary Tuolumne River in its lower course flowed in a wide and open valley above which the hills rise from 500 to 800 feet. Near the eastern boundary of the Sonora quadrangle the valley was probably about 1,500 feet deep, but still from 4 to 6 miles wide. The sharp slope of the Tertiary canyon is well shown by the outlines of the andesite area on the divide between the main Tuolumne River and its middle fork. The present canyon lies 1,500 feet below the bottom of the Tertiary valley. In the Yosemite quadrangle the valley deepened, and up toward Piute Creek it assumed a V-shaped cross section as well shown in Plate XXVIII. Farther north the main granite area formed an undulating plateau trenched to a depth of 1,500 to 2,000 feet by the Tertiary canyons.

APPENDIX.

LATE DEVELOPMENTS IN THE DREDGING INDUSTRY.

INTRODUCTION.

At present the dredging industry is by far the most important branch of placer mining in California. In 1909, out of a total of $9,104,433 derived from placers, $7,382,950 came from the dredging fields, mainly in Butte, Yuba, and Sacramento counties. In these fields the Quaternary gravels resting near the mouths of the canyons from the Sierra Nevada are the source of the gold, and thus the deposits do not strictly fall within the scope of the present volume, which deals with the Tertiary gravels. In view of the great development of this branch of the mining industry, however, a few words about the latest developments and the geology of the deposits may not be out of place. The principal dredging districts are at Oroville (described briefly on pp. 89–90), on Feather River; at Daguerre Point, on the Yuba, 12 miles above Marysville; and at Folsom, on American River. A smaller district was worked for some time near Camp Far West, on Bear River above Wheatland, but the gravels proved to be of low grade and difficult to work and operations were discontinued.

The gravels that contain enough gold to work are of moderate extent. The Folsom field, embracing about 13,000 acres, is the largest developed; in spite of active prospecting few other districts have been found. Smaller quantities of gravel are dredged in Siskiyou and Shasta counties. Two dredges are operating near Jenny Lind, in Calaveras County; one is working at Merced Falls, in Merced County; and one at La Grange, in Stanislaus County.

The depth of the gravels ranges from 25 to 80 feet. In part the gravels are coarse, cobbles up to a foot in diameter being by no means uncommon. They contain much sand and clay in places and are ill sorted. As the depth to bedrock does not increase greatly with the distance from the mouth of the canyon, it is inferred that the Quaternary rivers depositing the detritus had approximately the same grade as the present stream channels. The gravels almost universally rest on a false bedrock of volcanic tuff or hardpan. Some of them lie below the present river level; others rest on benches up to 100 feet above the channels of to-day. This tuff forms a sheet from 12 to 60 feet in thickness. Both at Oroville and along Yuba River auriferous gravel is found below it, but under present conditions this lower gravel can not be worked.

The gold is by no means everywhere confined to the bedrock surface; more commonly, indeed, it is distributed through the gravels or contained in one or more upper strata of gravel. Where the material is clayey, the gold is likely to be distributed throughout it. From this the engineers in charge have justly drawn the conclusion that the gravels were throughout deposited by overloaded rivers; probably the beds were laid down largely during the glacial epoch. The tenor of the gravels ranges up to 25 cents a cubic yard; it is said to be about 15 cents at Oroville and about 10 cents at Folsom. An average of the fields would probably show 12 cents a cubic yard. As the distance from the mouth of the canyon increases the gold becomes finer and the gravels poorer.

The gold is in fine flat scales but is comparatively easy to catch. More or less elaborate schemes involving coconut matting, mercury cups, and other devices were formerly used, but at the present the Hungarian riffle with mercury is almost solely employed in the sluices, with occasional amalgam traps.

The fineness of grain of the gold for the Oroville field is given in the following statement, kindly transmitted by Mr. Newton Cleaveland, in charge of the Yuba Consolidated Goldfields. The proportions of coarse and fine gold were determined by screening through screens of various sizes the numbers represent meshes to the linear inch of screen).

Percentage of coarse and fine gold in the Oroville district

[Examinations by Newton Cleaveland.]

	Per cent.
From four samples, aggregating 762.41 grains:	
60 and coarser	60.85
60 to 100	12.16
100 to 120	2.13
120 to 150	22.94
	98.08
From four samples, aggregating 743.66 grains:	
60 and coarser	47.25
60 to 100	16.4
100 to 120	2.67
120 to 150	2.88
150 and finer	30.8
	100.00
From four samples, aggregating 763.18 grains:	
60 and coarser	56.3
60 to 100	17.92
100 to 120	3.57
120 to 150	2.47
150 and finer	19.73
	99.99
From four samples, aggregating 724.57 grains:	
60 and coarser	55.67
60 to 100	20.54
100 to 120	3.72
120 to 150	2.06
150 and finer	18.01
	100.00
From four samples, aggregating 780.51 grains:	
60 and coarser	70.23
60 to 100	9.7
100 to 120	2.7
120 to 150	1.27
150 and finer	16.09
	99.99

In the other districts the gold has approximately the same size of grain. Occasionally pieces of a value of 50 to 80 cents are found, but this is wholly exceptional. The gold is of high grade in value, its fineness measuring 915 to 930. A little platinum, iridosmine, etc., are associated with the gold; the quantity is very small, but somewhat larger at Oroville than in the other districts. The platinum, which does not amalgamate, is separated by panning from the black sand of the weekly clean-up of each dredge. The production of platinum from all districts amounts to only a few hundred ounces a year.

YUBA DREDGE FIELD.

The Yuba field, 12 miles above Marysville, at Daguerre Point, is situated where the first greenstone hills of Yuba County emerge from the Quaternary covering on the south side of the river. Two companies are operating. The Yuba Consolidated Goldfields has 12 dredges with buckets of 7 cubic feet capacity, and one now building with a capacity of 15 cubic feet, a ladder 125 feet in length, and a displacement of 2,400 tons. This company breaks an average of about 45,000 cubic yards of gravel daily. The area of the property is 3,500 acres. Below this is the property of the Marysville Gold Dredging Co. (usually referred to as the Marigold), which operates three dredges. The available dredging land on Yuba River has a total area of about 5,000 acres; it extends along the river for a distance of about 7 miles and has a width of 1 to 2 miles.

The field is only slightly above the river level and is covered to a depth of 40 feet or less by the old tailings brought down by the river from the hydraulic mines higher up in the mountains. Before these tailings were deposited the low bars rose to a height of 15 to 20 feet above the water level. Above Daguerre Point, on the north side of the river, the gravels rest on greenstone bedrock, but elsewhere over the entire area they lie on a stratum of hardpan or compact clay, which on the north side of the river rises to low rolling hills. Below the clay in places is volcanic tuff, similar to that at Oroville, described on pages 89–90 and probably derived from the same source, namely, the volcano of the Marysville Buttes. The bedrock brought up by the dredges does not usually show evidence of the presence of volcanic material.

The gold production of the Yuba dredging district was $2,441,919 in 1909; the district entered the list of producers in 1903.

FOLSOM DREDGE FIELD.[1]

The district at the mouth of the canyon of American River is considered the largest in the State, comprising about 13,000 acres of Quaternary gravels. It extends from Folsom, in Sacramento County, mainly along the south side of the river for a distance of about 7 miles, with a width of 1 to 2 miles. Two companies are operating—the Natomas Consolidated Co. of California, which has eight dredges working at several places west of Folsom, and the New England Exploration Co., working what is known as the Ashburton dredge. In 1909 the Natomas Consolidated Co. turned over 321.48 acres and handled 13,975,185 cubic yards of gravel at a cost of 3.6 cents a cubic yard while digging to an average depth of 27 feet on ground ranging from 19 to 70 feet in depth.[2] The values vary from 6 to 18 cents a cubic yard. The dredge production of Sacramento County in 1909 was $1,534,136; the district entered the ranks of the producers in 1902.

The first areas worked were the "bars" on the north side of the river, including Mississippi, Sailor, and Sacramento bars, all of these being only a few feet above river level.

Along the south side of the river extends a wide belt of dredging ground of sandy gravel, 20 to 25 feet deep. This gravel, the bedrock of which is about 25 feet above the river, is now worked at several places. Like the gravel of the bars, it rests on a false bedrock of white volcanic ash, which outcrops in the Orangevale Bluff, north of the river, and at other points on higher ground south of the river. Only at two places along Willow Creek, within the area actually exploited, does the real bedrock (granite and slate) appear under the gravel.

There is also a higher belt of terrace gravel farther south; this is worked at the present time mainly on Rebel Hill, 2 miles southwest of Folsom, a locality in which the early miners carried on much shallow hydraulic and drifting work. This belt appears to represent an older Quaternary channel, which came down from Mormon Island and Blue Wing Ravine and continued along the upper course of Willow Creek. Here the channel is 400 feet wide and has been worked at several places from shafts 60 to 80 feet deep. At Rebel Hill this gravel spreads out considerably and is 50 feet deep, the volcanic ash bedrock lying about 50 feet above the river. In this area the gravel is covered by 6 to 10 feet of red clayey loam carrying some gold, and the gravel itself is clayey. There are two principal pay streaks—one at 34 feet below the surface; the second at a depth of 50 feet, resting on the false bedrock.

The dredges now building have a bucket capacity of 13½ cubic feet and a ladder 118 feet long and are designed to dig 55 feet below water level. The sluice area on these dredges comprises about 7,200 square feet, the boat itself being 152 feet long.

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[1] See also pp. 164-165.

[2] Yale, C. G., Mineral Resources U. S. for 1909, pt. 1, U. S. Geol. Survey, 1911, p. 282.

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